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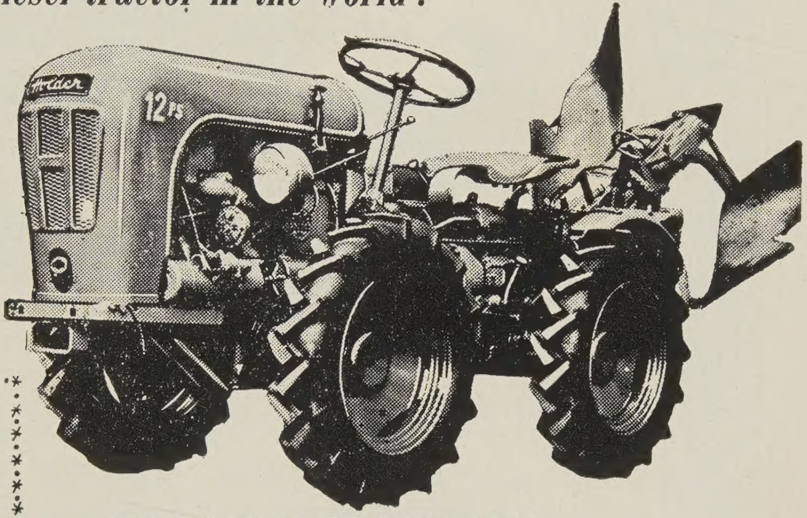

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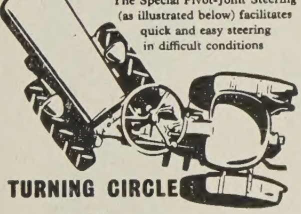

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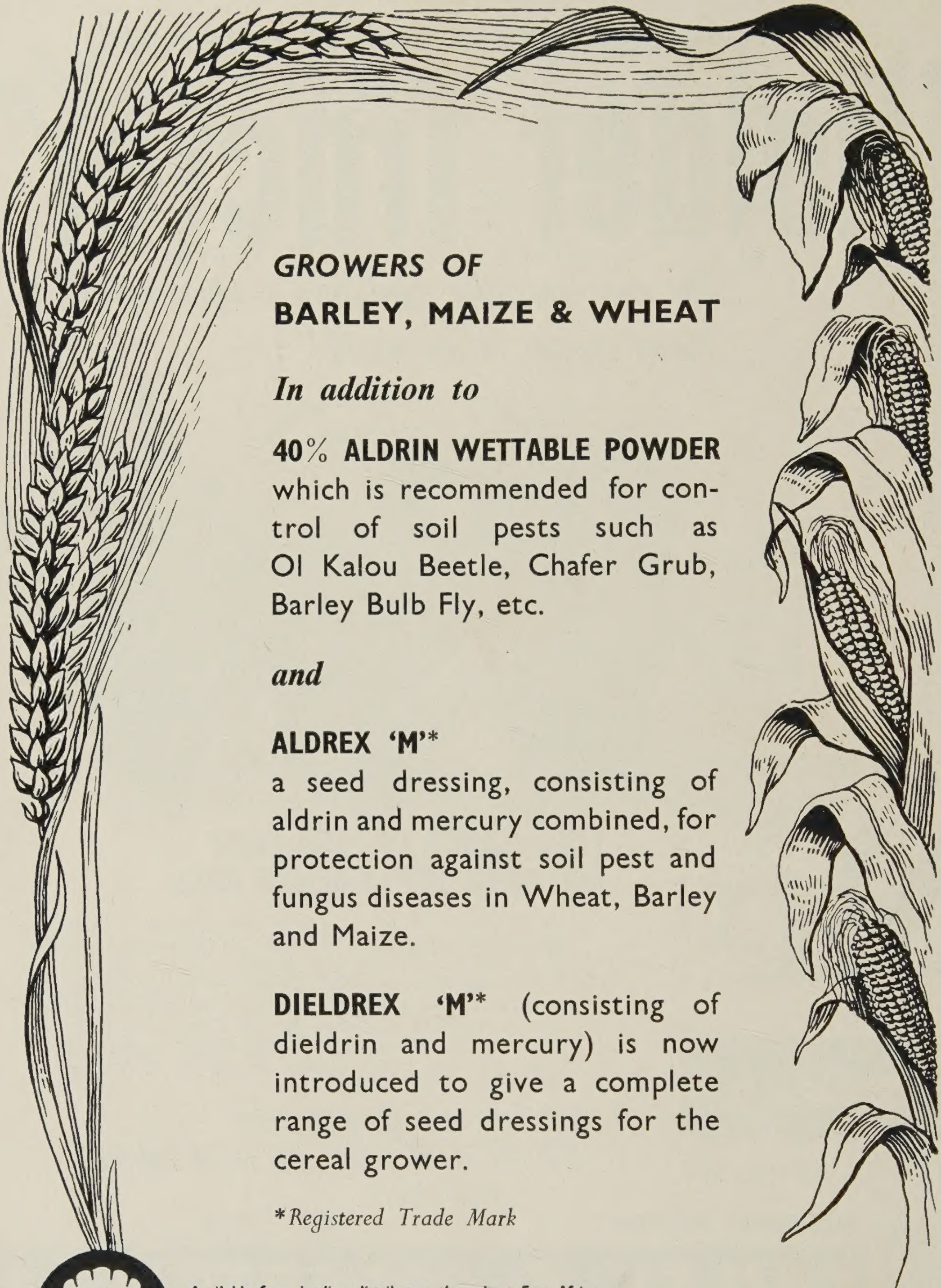

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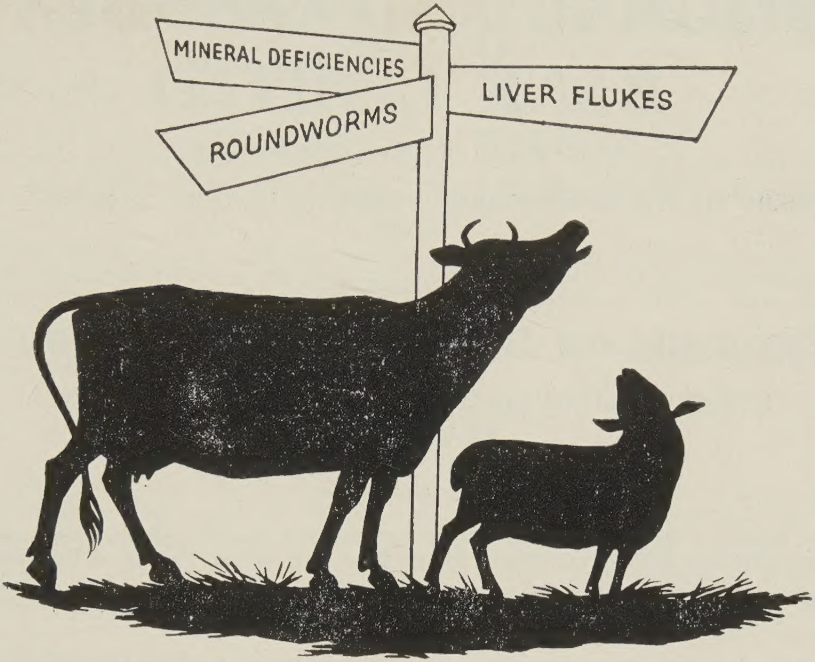

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Readers are reminded that all agricultural enquiries, whether they relate to articles in the Journal or not, should be addressed to the local Director of Agriculture, and not to the Editor.

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EDITORIAL

With this number the first in our 26th year of publication, the title of this Journal is changed. After 25 years as the EAST AFRICAN AGRICULTURAL JOURNAL, the East African Agricultural and Fisheries Research Council, with the approval of the Secretary of State has decided that we now become the EAST AFRICAN AGRICULTURAL AND FORESTRY JOURNAL. The Secretary of State has also kindly consented to carry part of the cost of the Journal out of the Colonial Development and Welfare Fund.

The format will remain the same, so that our readers will not be inconvenienced by change in size or shape. The contracted title will now be *E. Afr. agric. for. J.* and reference should be made to it in this form.

STUDIES OF INTERCROPPING

I—MAIZE OR SORGHUM WITH GROUNDNUTS

By A. C. Evans, Department of Agriculture, Dar es Salaam, Tanganyika

(*Received for publication on 29th March, 1960*)

Little quantitative information exists in Tanganyika on the comparative merits of intercropping and pure stands. It is exceptional for the peasants to plant pure stands. Unless sound evidence is obtained that production from pure stands is appreciably higher than that from mixed cropping, and that there are advantages such as reduced labour input, pest and disease control, and convenience, it will not be possible to introduce rotational systems of agriculture based on pure stands so long as the hoe remains the most important agricultural implement. In fact if intercropping has decided advantages over pure stands then pure stands would only be essential if harvesting has to be mechanized.

There is a considerable body of literature on intercropping, but only too frequently records are given of pure stands of one crop and of that crop interplanted with another, so that it is not possible to obtain a complete comparison of pure stands of two crops with the intercrops. Again, plant populations are rarely recorded, and when they are the populations of the intercrops often differ from those of the pure stands so that the effects of populations on yields are not clear. Such pure stands usually have higher populations than the intercrops.

Three experiments were carried out during 1957, one at Ilonga on maize with groundnuts, and two at Mwanhala on maize with groundnuts and sorghum with groundnuts. At both stations rains were very favourable and wilting was not recorded, thus competition for water played at most a minor part in these experiments. On the fertile soil at Ilonga, fertilizers were not applied, as previous experience has shown that they are not required, at least for pure stands. At Mwanhala where the soil is not very fertile 130 lb. per acre of double superphosphate were applied broadcast before planting, and 130 lb. per acre of sulphate of ammonia were top-dressed. The experiments were repeated in 1958 at Mwanhala, the sites being interchanged. In these experiments Asiriya Mwitunde groundnuts, Katambili maize and Dobbs sorghum were planted.

In order to evaluate the role of plant population in intercropping, the following design was used. All combinations of high (H), medium (M) and low (L) populations of the two crops were planted together with pure stands at the same populations, giving 15 treatments. Each crop gave three yields in pure stand and nine intercrops. These were analysed as a 3 × 4 factorial experiment for each crop.

RESULTS

1957

The plant populations aimed at were not always achieved, but sufficiently differing populations were obtained for the purposes of this study, Table 1. The population given for 'intercrop' has been averaged over the three intercrop populations.

TABLE 1.—HARVEST POPULATIONS, 1000 PER ACRE, 1957
M: maize; S: sorghum; G: groundnuts.

TREATMENT	ILONGA		MWANHALA			
	M	G	M	G	S	G
HIGH						
Pure stand	11·6	27·9	11·0	47·5	22·0	54·9
Intercrop	11·4	24·8	10·7	44·9	28·1	46·4
MEDIUM						
Pure stand	9·1	20·5	7·7	42·3	17·2	37·6
Intercrop	8·8	20·3	7·7	33·3	17·1	37·3
LOW						
Pure stand	6·1	16·5	3·9	27·4	16·8	29·4
Intercrop	6·3	15·3	4·6	24·7	11·7	27·8

At Ilonga, populations for both intercrop and pure stands were very comparable. The low maize "population" was rather higher than intended, four thousand per acre, since a high proportion of the plants tillered, producing two stems. At Mwanhala, the high population for the pure stand of groundnuts was rather high as was the low population for the pure stand of sorghum.

TABLE 2.—THE EFFECTS OF FOUR GROUNDNUT POPULATIONS ON THE YIELD OF MAIZE AT THREE POPULATIONS, LB. PER ACRE
ILONGA, 1957

Maize Population

GROUNDNUTS	MAIZE			MEANS
	L	M	H	
O	1,733	2,623	2,961	2,439
L	1,686	2,176	2,819	2,227
M	1,728	2,138	2,696	2,187
H	1,803	2,329	2,544	2,225
MEANS	1,737	2,317	2,755	

Significant Differences	Body of Table	Mean Maize Populations	Mean Groundnut Populations
5%	290	145	168
1%	387	192	223

There are highly significant and appreciable reductions in yields of maize as populations are reduced. The reduction is greatest in the absence of groundnuts and least in the presence of the high groundnut population. The mean yield of maize is significantly reduced in the presence of groundnuts. At the low maize population the presence of groundnuts has no effect on yield. At the medium and high maize populations there are significant reductions in the presence of groundnuts but no consistent relation is shown between these reductions and the levels of groundnut population, there being a mean reduction of 340 lb. per acre due to the presence of groundnuts.

TABLE 3.—THE EFFECTS OF FOUR MAIZE POPULATIONS ON THE YIELD OF GROUNDNUTS AT THREE POPULATIONS, LB. OF KERNEL PER ACRE

Ilonga, 1957

MAIZE	GROUNDNUT			MEANS
	L	M	H	
O	830	738	814	794
L	415	436	546	466
M	281	372	346	333
H	215	194	280	229
MEANS	435	435	497	

Significant Differences	Body of Table	Mean Maize Population	Mean Groundnut Population
5%	113	57	65
1%	151	76	87

Yields of groundnuts are not affected by groundnut populations at any of the maize populations. There are however highly significant and progressive reductions in mean yield with increasing maize populations.

TABLE 4.—THE EFFECTS OF FOUR GROUNDNUT POPULATIONS ON THE YIELD OF MAIZE AT THREE POPULATIONS, LB. PER ACRE

Mwanhala, 1957

GROUNDNUTS	MAIZE			MEANS
	L	M	H	
O	1,416	1,990	1,668	1,691
L	920	1,416	1,196	1,177
M	886	1,002	722	870
H	954	840	722	835
MEAN	1,044	1,312	1,077	

TABLE 4.—THE EFFECTS OF FOUR GROUNDNUT POPULATIONS ON THE YIELD OF MAIZE AT THREE POPULATIONS, LB. PER ACRE—(*Contd.*)

Significant Differences	Body of Table	Mean Maize Population	Mean Groundnut Population
5%	283	142	164
1%	380	190	219

At Mwanhala the medium maize population gave a significantly higher mean yield than either of the other populations. This superiority is shown at all populations of groundnuts except for the highest within which the pattern did not occur. The presence of a low groundnut population reduced yields by an average of 510 lb. per acre, further increases in groundnut population caused a further reduction of some 300 lb.

TABLE 5.—THE EFFECTS OF FOUR MAIZE POPULATIONS ON THE YIELD OF GROUNDNUTS AT THREE POPULATIONS, LB. PER ACRE

Mwanhala, 1957

Maize	Groundnut			Means
	L	M	H	
O	1,232	1,380	1,340	1,317
L	820	868	798	828
M	572	732	640	648
H	516	552	594	554
Means	785	883	843	

Significant Differences	Body of Table	Mean Maize Population	Mean Groundnut Population
5%	149	87	74
1%	199	115	99

The low groundnut population gave a significantly lower mean yield than the medium population but the yield from the high population was not significantly different from either of the others, Table 5. The presence of maize caused very appreciable and significant reductions in yield.

TABLE 6.—THE EFFECTS OF FOUR GROUNDNUT POPULATIONS ON THE YIELD OF SORGHUM AT THREE POPULATIONS, LB. PER ACRE

Mwanhala, 1957

Groundnut	Sorghum			Means
	L	M	H	
O	586	674	674	645
L	370	431	761	521
M	222	471	471	388
H	391	438	451	427
Means	392	504	589	

Significant Differences	Body of Table	Mean Sorghum Population	Mean Groundnut Population
5%	196	98	113
1%	263	131	150

Mean yields of sorghum increased significantly but not very appreciably with increasing sorghum populations. This is largely due to the particularly high yield produced by the high sorghum population at a low groundnut population and the rather low yield at a low sorghum population with medium groundnut population. An examination of the experimental data did not show any particularly abnormal plot yields to account for these yields. The presence of groundnuts reduced yields appreciably, particularly at the two higher populations.

TABLE 7.—THE EFFECTS OF FOUR SORGHUM POPULATIONS ON THE YIELD LB./ACRE OF GROUNDNUTS AT THREE POPULATIONS

Mwanhala, 1957

Sorghum	Groundnut			Means
	L	M	H	
O	1,622	1,514	1,561	1,566
L	835	1,175	1,004	1,005
M	946	1,012	1,137	1,032
H	783	764	869	805
Means	1,047	1,116	1,143	

Significant Differences	Body of Table	Mean Groundnut Population	Mean Sorghum Population
5%	150	75	88
1%	202	101	117

The mean yield of groundnuts was significantly higher at the high groundnut population compared with the low population, with the medium population giving an intermediate yield. The yield increases were not high. The presence of sorghum had a very appreciable effect in reducing groundnut yield, the low and medium populations causing a loss of some 550 lb. and the high population about 750 lb.

Interaction was significant at the 1 per cent level of probability. This is probably due to the relatively greater reduction in yield shown by the low groundnut population compared with the medium and high populations at the low and medium populations of sorghum. The greatest relative reduction in groundnut yield was brought about by the low sorghum population. The presence of sorghum reduced the mean groundnut yield to an average of 69 per cent, but the presence of groundnuts only reduced the mean yield of sorghum to an average of 60 per cent.

A summary of the overall effect of one crop on the other in 1957 is given in Table 8.

Table 8.—Yields Expressed as Percentages, Showing Variable Effects of One Crop in Reducing Yields of the Other

Population Level (A)	Maize			Groundnuts		
	Ilonga	Mwanhala	Sorghum Mwanhala	Ilonga	Mwanhala (B)	Mwanhala (C)
Nil ..	100	100	100	100	100	100
L ..	93	70	81	59	63	64
M ..	92	51	60	42	49	66
H ..	93	49	66	29	42	51
Mean Reduction	7	43	31	57	49	40
Nil Yield	2,439	1,691	645	794	1,317	1,566

(A) Of other crop. (B) Under maize.
(C) Under sorghum.

The above results describe the competitive effects of one crop on the other. To obtain a comparison between pure stands and intercropping, the yields of both crops from one acre of intercropping can be compared with half-acre yields of similar and different populations. This comparison is based on the assumption that the same amount of labour is put into producing one acre of intercrop and two half-acres of pure stands. A further method of comparison is to calculate the amount of land that should be cultivated in pure stands to produce equivalent yields to those obtained from one acre of intercropping at different plant population levels. Both methods of comparison are described below.

Table 9.—Comparison of Yields (Lb.) from One Acre of Intercropping and Two Half-acres of Pure Stands—Ilonga, 1957

Population		Intercrop 1 acre		Pure Stands ½ acre	
Maize	Groundnuts	Maize	Groundnuts	Maize	Groundnuts
L	L	1,686	415	867	397
L	M	1,728	436		
L	H	1,803	546		
M	L	2,176	281	1,312	397
M	M	2,138	372		
M	H	2,329	346		
H	L	2,819	215	1,481	397
H	M	2,696	194		
H	H	2,544	280		

In Table 9 the mean yield of groundnuts over the three populations in pure stand is given since population had no effect on yield at Ilonga. At the low population of maize there is a clear gain of about 100 per cent of maize and no loss of groundnuts in favour of intercropping at similar populations levels. At the medium population of maize the average increase in yield of intercropped maize, 900 lb. is offset by a slight mean reduction in groundnuts of some 60 lb. At the high population of maize an increased maize yield of 1,370 lb. from intercropping results in a mean loss of 170 lb. of groundnuts. If the yield at the highest maize population in pure stand is used as a basis for comparison then intercropping at a low maize population with an adequate groundnut population still gives an overall gain, 220 lb. of maize and 70 lb. of groundnuts. At the medium maize population the loss in groundnuts given above is compensated for by rather lower increases in maize of 1,200 lb.

If maize is the crop which is primarily desired, then intercropping a high maize population with an adequate population of groundnuts leads to an overall gain in produce. However, if groundnuts are required, then intercropping with a low maize population would not lead to a loss of groundnuts and a reasonable maize yield would be obtained as well.

At the low population of maize at Mwanhala, there is a clear gain in intercrop yields for both maize and groundnuts at all groundnut populations. At the medium maize population there is an appreciable increase in maize yield at the low groundnut population.

The yield of groundnuts from one acre of intercrop is not significantly different from the yield of half-an-acre in pure stand. At the high maize population there is a general reduction in yield of groundnuts and maize except for maize at the low groundnut population.

TABLE 10.—COMPARISON OF YIELDS (LB.) FROM ONE ACRE OF INTERCROPPING AND TWO HALF-ACRES OF PURE STANDS—MWANHALA, 1957

Population Level		Intercrop		Pure Stands	
Maize	Groundnuts	Maize	Groundnuts	Maize	Groundnuts
L	L	920	820	708	616
L	M	886	868		690
L	H	954	798		670
M	L	1,416	572	995	616
M	M	1,002	732		690
M	H	840	640		670
H	L	1,196	516	834	616
H	M	722	552		690
H	H	722	594		670

Taking the yields of maize and groundnuts at medium populations in pure stand as the standard, there is clearly no overall loss in yield from intercropping a low maize population with groundnuts. Groundnuts in a low maize population probably gave the best return.

TABLE 11.—COMPARISON OF YIELDS (LB.) FROM ONE ACRE OF INTERCROPPING AND TWO HALF-ACRES OF PURE STANDS—MWANHALA, 1957

Population Level		Intercrop		Pure Stands	
Sorghum	Groundnuts	Sorghum ghum	Groundnuts	Sorghum ghum	Groundnuts
L	L	370	835	323	783
L	M	222	1,175		
L	H	391	1,004		
M	L	431	946	323	783
M	M	471	1,012		
M	H	438	1,137		
H	L	761	783	323	783
H	M	471	764		
H	H	451	869		

Since differences in yield are far from significant for the three populations of both crops in pure stand, only the means are given as standards.

In this experiment sorghum midge caused serious damage to the sorghum heads and materially reduced yields. At all populations intercropping is markedly superior to cropping in pure stands, medium populations of both crops giving the best return. This experiment can be regarded as an example of the "insurance" value of intercropping.

The value of intercropping can also be assessed by calculating the area of land in pure stands required to produce the yield of an acre of intercrop.

TABLE 12.—ACRES OF CROP UNDER PURE STAND REQUIRED TO PRODUCE THE YIELD OF ONE ACRE OF INTERCROPPING AT ALL COMBINATIONS OF PLANT POPULATIONS, 1957

		A			B		
Grain	Groundnuts	Ilonga	Mwanhala Maize	Mwanhala Sorghum	Ilonga	Mwanhala Maize	Mwanhala Sorghum
L	L	1·07	1·05	1·06	1·47	1·31	1·14
L	M	1·10	1·08	1·05	1·59	1·26	1·16
L	H	1·27	1·06	1·20	1·71	1·27	1·31
M	L	1·07	1·11	1·22	1·17	1·17	1·22
M	M	1·17	1·03	1·32	1·31	1·03	1·37
M	H	1·21	·88	1·35	1·32	·90	1·38
H	L	1·21	·97	1·61	1·21	1·14	1·61
H	M	1·14	·76	1·17	1·17	·83	1·20
H	H	1·19	·79	1·20	1·20	·87	1·23
Mean % increase or decrease		+16	—1	+24	+34	+9	+29

A.—Calculated on the basis of maximum yield in pure stand.

B.—Calculated on the basis of the comparable population in pure stand.

In two of the experiments in 1957, maize and groundnuts at Ilonga and sorghum and groundnuts at Mwanhala, there is an appreciable saving of land and labour in favour of intercropping for both methods of calculation. For maize and groundnuts at Mwanhala, intercropping required less land than pure stands at low maize populations, but at high maize populations less land in pure stands was needed. With medium populations of maize approximately the same amount of land was required. Since in this experiment it was found that intercropping at low maize populations gave the most favourable returns, the saving of land by using high populations in pure stands is negatived by loss of produce.

1958

The two experiments at Mwanhala were repeated in 1958, the sites being interchanged and fertilizers were not reapplied. The rainfall régime was in great contrast to that of 1937, three drought periods occurring—a three weeks drought in January, a two weeks drought in February and almost a four weeks drought in March/April. Thus results have been obtained under very contrasting conditions in the two years.

Desired populations were nearly achieved in the case of maize. For sorghum and groundnuts final stands were lower than desired, but were sufficiently different for the purposes of the experiment.

TABLE 13.—COMPARISON OF YIELDS (LB.) FROM ONE ACRE OF INTERCROPPING AND TWO HALF-ACRES OF PURE STANDS OF MAIZE AND GROUNDNUTS—MWANHALA, 1958

Population Level		Intercrop		Pure Stands	
Maize	Groundnuts	Maize	Groundnuts	Maize	Ground nuts
L	L	361	192	300	109
L	M	428	200		105
L	H	367	226		139
M	L	620	111	320	109
M	M	469	211		105
M	H	422	238		139
H	L	458	132	242	109
H	M	292	190		105
H	H	303	241		139
Significant Differences 5%		83	47	42	24

As in 1957, Table 13 shows that the medium maize population gave the highest yield and the low groundnut population the lowest yield. Also, the presence of groundnuts has again caused some reduction in maize yields. In 1957 the medium and high groundnuts populations reduced maize yields by approximately 800 lb. or 50 per cent. In 1958 the reduction was about 200 lb. or 35 per cent. In a year of unfavourable rainfall it might have been expected that the relative reduction would have been greater than in a favourable year. For groundnuts a generally similar result was obtained, a lower absolute reduction of 40 lb. as against 600 lb. or about 20 per cent as against 45 per cent in 1957.

At corresponding levels of populations the yield from one acre of intercrop is greater than that from two half-acres of pure stand. Taking the highest yields from cropping in pure stands as the standard, i.e. 320 lb. maize and 139 lb. groundnuts, four of the intercropping treatments show a reduced yield of one crop, but this reduction is more than balanced by a gain in the other. Not one intercropping treatment shows a reduction below these standards in both crops.

TABLE 14.—COMPARISON OF YIELDS (LB.) FROM ONE ACRE OF INTERCROPPING AND TWO HALF-ACRES OF PURE STANDS OF SORGHUM AND GROUNDNUTS MWANHALA, 1958

Population Level		Intercrop		Pure Stands	
Sorghum	Groundnuts	Sorghum	Groundnuts	Sorghum	Groundnuts
L	L	130	226	104	99
L	M	81	185		
L	H	85	232		
M	L	130	212	84	99
M	M	111	188		
M	H	47	212		
H	L	62	218	87	99
H	M	87	223		
H	H	107	223		
Significant Differences 5%		27	16	14	N.S.

In Table 14 the yield of groundnuts from intercropping shows a marked superiority for all treatments over that from the pure stand. The yield of sorghum was miserably low generally. In a number of instances the yield from intercropping was significantly lower than that from the pure stand. Any reduction was, however, small and more than compensated for by the increased production of groundnuts.

In the above experiments the distribution of both crops on the ground was uniform. It was thought that by a grouping arrangement of the intercrops it might be possible to increase yield as compared with a uniform distribution. Three population levels of intercrop were tested: high maize—low groundnuts, medium maize and groundnuts, low maize—high groundnuts, in the following arrangements:—

1. Alternate rows maize and groundnuts.
2. Maize grouped at three plants per hill, groundnuts uniformly distributed.
3. Maize and groundnuts uniformly distributed in the same row.

In addition both crops were grown in pure stands at the appropriate populations in the absence of weeds and weeded between the rows only. The latter treatment was included to compare the effects of weeds and a low growing intercrop. Weeds grow well at Ilonga where the experiment was planted, the weeds grew taller than the groundnuts in pure stand.

TABLE 15.—COMPARISON OF THE YIELDS (LB.) FROM TWO HALF-ACRES OF PURE STANDS, CLEAN AND WEEDED BETWEEN ROWS ONLY, AND ONE ACRE OF INTERCROPPING WITH DIFFERENTIAL PLANT DISTRIBUTION ILONGA, 1958

Population Level		Crop	Pure Stands		Intercrop		
Maize	G'nuts		Weedy	Clean	Alternate	Grouped	Uniform
H	L	Maize	726	713	1,230	1,321	1,525
		G'nuts	122	236	193	200	154
M	M	Maize	557	837	1,085	1,110	1,218
		G'nuts	179	299	255	342	329
L	H	Maize	337	454	788	699	720
		G'nuts	237	330	455	492	485
Significant differences 5%		Maize	143		290		
		Groundnuts	87		99		

There is clearly no striking advantage to be gained from growing the crops in alternate lines or grouping the maize as compared with a uniform distribution in the row.

The presence of weeds in the row caused appreciable reductions in yields of pure stands except for the high population of maize. In each crop the presence of weeds in the row brought about approximately the same percentage of reduction as that caused by the presence of another crop. However, the percentage reduction caused by weeds and intercropping to groundnut yields was approximately double that in the case of maize yields as is shown in Table 16.

TABLE 16.—COMPARISON OF RELATIVE EFFECT OF WEEDS ON TWO CROPS

CROP	PERCENTAGE REDUCTION	
	By Weeds	By another Crop
Maize	20·1	18·5
Groundnuts ..	40·0	45·0

On the above evidence, it might be said that the best weed is another crop.

Two small experiments were planted at Mnacho and Mtama in the Southern Province, comparing two levels of populations, high maize with low groundnuts and high groundnuts with low maize. The results are shown in Table 17.

TABLE 17.—COMPARISON OF YIELDS (LB.) FROM ONE ACRE OF INTERCROPPING AND TWO HALF-ACRES OF PURE STANDS—SOUTHERN PROVINCE, 1958

Population Level		Intercrop		Pure Stands	
Maize	Groundnuts	Maize	Groundnuts	Maize	Groundnuts
MTAMA—					
H	L	923	575	552	465
L	H	1,134	862	567	654
Significant Differences 5%		270	80	135	40
MNACHO—					
H	L	1,644	192	1,163	101
L	H	1,550	151	877	61
Significant Differences 5%		238	64	119	34

At both sites the production of both crops was appreciably greater from intercropping at comparable levels of plant population. At Mtama the yield from half an acre of groundnuts in pure stand at the high population level was significantly greater than that from an acre of mixed cropping with a low groundnut population. However, the increased yield of maize, 371 lb., would compensate for this loss of 79 lb. of groundnuts so long as the price of groundnuts does not rise to rather more than four times that of maize.

TABLE 18.—ACRES OF CROPS UNDER PURE CROP REQUIRED TO PRODUCE THE YIELD OF ONE ACRE OF INTERCROPPING AT ALL COMBINATIONS OF PLANT POPULATIONS, 1958

		MWANHALA				ILONGA	
		A		B		A	B
Grain	G'nuts	Maize	Sorghum	Maize	Sorghum	Maize	
L	L	1·25	1·77	1·47	1·77		
L	M	1·39	1·32	1·67	1·32		
L	H	1·38	1·58	1·48	1·58	1·14	1·52
M	L	1·37	1·69	1·48	1·84		
M	M	1·49	1·48	1·73	1·61	1·23	1·28
M	H	1·51	1·30	1·51	1·35		
H	L	1·19	1·40	1·50	1·46	1·14	1·40
H	M	1·12	1·54	1·56	1·62		
H	H	1·34	1·63	1·50	1·73		
Mean	%	+34	+52	+54	+59	+17	+40

Increase or decrease:—

A. Calculated on the basis of maximum yield to pure stand.

B. Calculated on the basis of comparable population in pure stand.

In Table 18 the value of intercropping as against cultivation in pure stands is assessed on the basis of land required to give equal production. In 1958 intercropping at Mwanhala was clearly more economical in land use than pure stands. The rainfall in 1958 was much more typical of the area served by Mwanhala than that of the previous year. The amount of land required to produce a given amount of crop by cropping in pure stands was greater in 1958 than in 1957 for nearly every combination of crop populations, and the figures may well be more representative for the area. In a peasant economy using the hoe, the amount of land that can be cultivated is strictly limited. In these circumstances there can be little doubt that intercropping will lead to a greater production per unit input of labour.

At Ilonga, such a contrast between the results of the two years is not shown. At this station the rainfall in 1958 was far more favourable for crop production, both in amount and distribution, than at Mwanhala.

Discussion

The experiments were planned to obtain quantitative data on the effect of intercropping compared with cultivation in pure stands under different environmental conditions. At Mwanhala, the soil is of low fertility status and the annual rainfall low and irregularly distributed. At Ilonga, soil fertility is high and the rainfall usually adequate and reasonably well distributed. A wide range of plant populations was considered necessary to simulate the range found in peasant cultivation.

The results have shown generally that higher production is obtained by intercropping. The major exception found was at Mwanhala in 1957 where production in pure stands of maize and groundnuts at medium populations was rather greater than that obtained by intercropping high maize populations with groundnuts at all populations. This exception occurred during a particularly favourable rainfall season and such seasons are rare in the area.

It was not possible to carry out ancilliary observations such as shade and soil moisture measurements and soil or plant analyses to try to arrive at an explanation for the reciprocal reductions in yield when maize and groundnuts are grown together. The shading effect of maize on groundnuts would appear to be an obvious factor in reducing groundnut yield, but at Ilonga in 1958, there were no significant differences nor even a trend to suggest that by growing the crops in alternate rows or by grouping the maize in the row the yield of groundnuts could be increased.

In 1957 at Ilonga there was a highly significant and negative regression between maize and groundnut yields but such a relationship was not shown at Mwanhala. At this station there was however a similar relationship between sorghum and groundnut yields. In 1958 significant regressions were not obtained between groundnut yields and sorghum or maize yields at Ilonga. The design of the 1958 experiment was not suited to showing such a regression.

In both years, however, significant regression relationships were obtained between the yields of groundnuts and the population of the other corp. Yields of maize also in some cases showed a regression on groundnut population. Sorghum yields however did not.

In 1957 all three experiments showed highly significant and negative regressions between groundnut yields and maize or sorghum populations, Fig. 1 and 2. For Ilonga, an extrapolation of the linear regression for intercropped treatments cuts the abscissa at a point approximating to the mean yield of groundnuts in pure stand. For Mwanhala, for both maize and sorghum populations such an extrapolation cuts the abscissa at a point appreciably below that of the mean yield of groundnuts in pure stand. Thus the effect of a low maize population on groundnut yield at Mwanhala is much greater than at Ilonga. This may perhaps have been due to a greater competition of plant nutrients in the poorer soil at Mwanhala. Once a low population of maize has been established the regression lines run parallel at both stations representing a loss of about 48 lb. of groundnuts for each increase of one thousand maize plants per acre. Similarly an increase of one thousand sorghum plants reduced groundnut yields by an average of 23 lb. per acre.

In 1958, at Ilonga, the same relationship was shown as in 1957 between groundnut yields and maize populations, Fig. 2, an increase of one thousand maize plants reduced groundnut yields by 41 lb. per acre. At Mwanhala in 1958 groundnut yields were poor owing to low and erratic rainfall distribution. The presence of a wide range of maize and sorghum populations reduced groundnut yield slightly in the case of maize but not at all in the case of sorghum, Table 19.

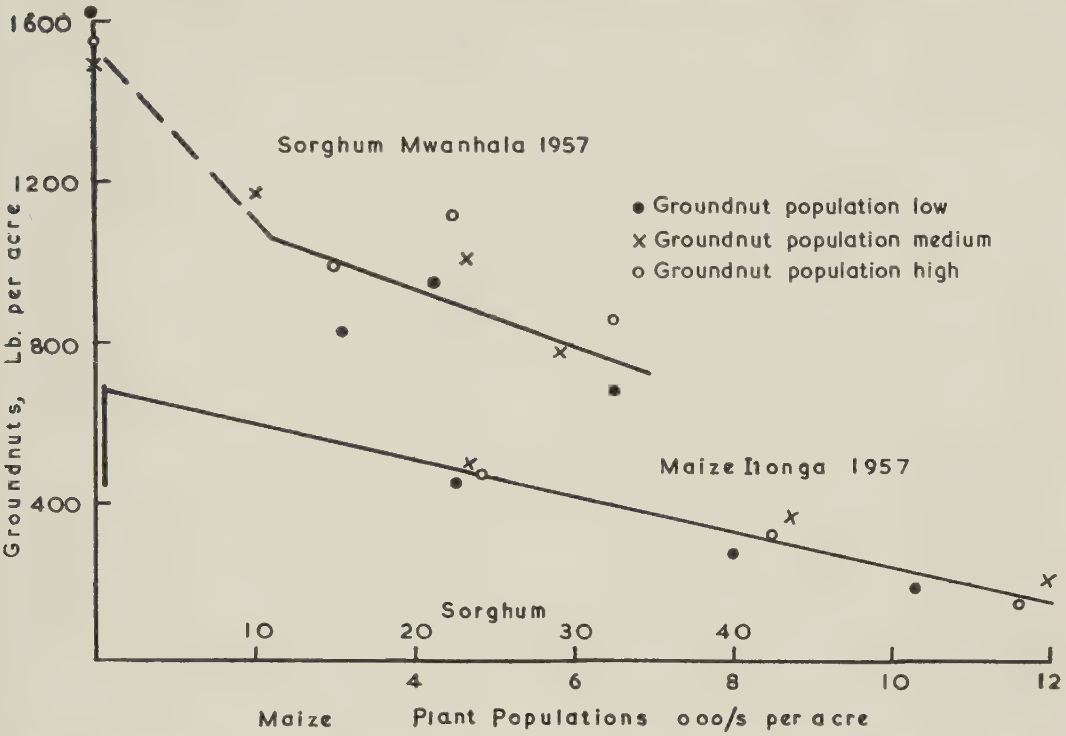

Fig. 1.—Showing the relationship between yield of groundnuts and plant populations of maize in 1957.

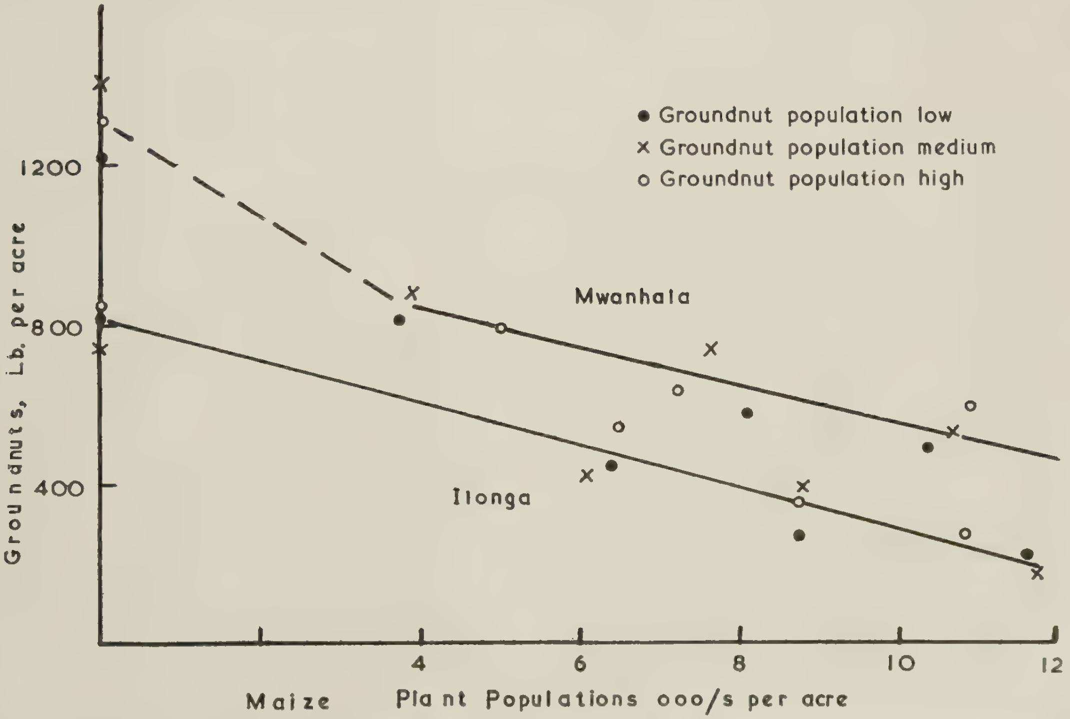

Fig. 2.—Showing the relationship between yield of groundnuts and plant populations of maize and sorghum.

TABLE 19.—EFFECT OF A RANGE OF POPULATIONS OF MAIZE AND SORGHUM ON GROUNDNUT YIELDS, AVERAGED OVER GROUNDNUT POPULATIONS, LB./ACRE MWANHALA, 1958

Plant Population Level of Maize or Sorghum	Groundnut Yields in presence of:	
	Maize	Sorghum
Absent	235	198
Low	206	214
Medium	187	204
High	188	221

At Ilonga in 1957, groundnut plant populations had no effect on maize yields at low maize populations and only a small effect at medium and high maize populations, averaging a reduction of about 25 lb. per acre for each increase of one thousand plants per acre. At Mwanhala in 1957, the average reduction in maize yield for an increase of one thousand groundnut plants was 26 lb. per acre.

At Mwanhala in 1957, a groundnut population of 27,000 plants per acre reduced the sorghum yield by 250 lb. further increases in population up to 48,000 plants per acre did not show any greater reduction. In 1958, yields of sorghum were very low and not affected by the presence of a wide range of groundnut populations.

SUMMARY

It is shown that over a wide range of populations intercropping maize or sorghum with groundnuts generally leads to a greater overall crop production per acre than by growing these crops in pure stands. This was found in two areas of contrasted levels of soil fertility and in two years of differing rainfall, one favourable, the other less favourable.

Yields were reduced by weeds growing in the row to the same extent as by growing another crop.

ACKNOWLEDGEMENTS

I am indebted to the following officers who carried the experiments, F. M. Spencer at Ilonga, J. Russell and D. B. Scott at Mwanhala and T. W. J. Smethurst in the Southern Province and to E. W. Russell of East African Agriculture and Forestry Research Organization and A. Sreedharan for helpful discussions and again to the latter who carried out the necessary statistical analyses.

REVIEW

MIST PROPAGATION OF CUTTINGS by Patricia Rowe-Dutton, published by Commonwealth Agricultural Bureaux, Farnham Royal, Bucks, England, 1959, pp. 135, price 10/-.

This digest covers most angles of the propagation of cuttings by the mist spray technique. The electronic leaf one so often reads of in horticultural literature these days, is fully described, as are various other devices.

A chapter on mist propagation structures describes a unit suitable for the large nursery, also a Bubble mist unit for the home gardener. Also dealt with in some detail are water pressure, rooting media, leaching and nutrition, shading and hardening off of rooted cuttings.

The book has special appeal to those interested in the vegetative propagation of tea, coffee, or cacao. Though none of these species are dealt with at any length, the principles of mist propagation are so clearly set out as to be of great value to the plantation propagator. At present only a few mist propagators are in use in East Africa. This book will clarify many points which may have puzzled the operator.

The small grower in the tropics need hardly go to the lengths of mist propagation, plastic covered frames under shade, properly handled, fill most of his needs. But to anyone interested in plant propagation at all, the book is well worth 10/- if only for the appendix, showing results obtained by mist propagation of over 200 genera. W. B. M.

SOME INTERNAL PARASITES OF GAME ANIMALS IN KENYA

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Although many of the internal parasites found in game animals have been described, it is often difficult for the non-specialist to obtain information on this subject as the reports are widely scattered and frequently contained in journals published many years ago. The purpose of this article is to describe the more common internal parasites encountered by the authors in the zebra, the wildebeest and Thomson's and Grant's gazelle in Kenya. We feel that the information may interest game wardens, naturalists and hunters who will have seen the parasites frequently, but lacked access to further information. As well as giving a brief description of each species and its location in the host, we have outlined the life-cycle, and, where this is not known, the probable life-cycle based on analogy with some closely related host-parasite system, e.g. many of the species of worms found in the zebra are almost identical to those found in the horse, and their life-cycles are almost certainly similar. No attempt has been made to include all of the parasites found in these animals, only the more numerous or obvious being described.

ZEBRA (*Equus burchellii*)

Abdominal Cavity.—When the abdominal cavity is opened variable numbers of thin, white worms 5 to 10 cm. long are frequently observed lying on the peritoneal covering of the intestine; the tail ends of the worms are spirally coiled (Plate III, fig. (*c*)). They are members of the genus *Setaria*. The females lay large numbers of microscopic larvae (microfilariae) which pass into the blood stream of the host. Transmission from one zebra to the other is effected by a blood-sucking insect. The insect involved is at present unkown, although in two species of *Setaria* found in the bovine, mosquitoes and stable flies (*Stomoxys calcitrans*) are known to be the respective vectors.

Stomach.—Two parasites are commonly observed in the stomach of the zebra.

The first of these is a small white worm about 2 cm. long. The males are slightly smaller and more slender than the females and their tails are spirally coiled. These nematodes belong to the genus *Habronema*. The females lay larvae which are passed on to the ground in the faeces of the host. No further development of the parasite is possible unless the larvae are ingested by maggots or flies developing in the dung. In the horse, which carries a similar parasite, the flies involved are the house fly (*Musca domestica*) and the stable fly. The larvae develop in the fly-maggot and, when the latter becomes adult, migrate into the mouth parts. The stable flies inject the larvae directly into the blood stream when feeding, while the larvae in the house fly are able to infect only when the latter feeds on open wounds. It is also possible that horses may become infected by swallowing flies which have fallen into their food or drinking water. The nematode larvae pass to the stomach of the host where they grow to maturity.

In horses, *Habronema* larvae deposited in wounds may produce a dermatitis characterized by firm lumpy lesions covered with soft brownish material ("summer sores"). It seems very possible that this may also occur in the zebra but to our knowledge has not been recorded.

The second parasite is the maggot or larvae of *Gastrophilus*, the bot-fly. These maggots are about 2 cm. long, segmented, and red in colour (Plate II, fig. (*b*)). They are frequently found in dense clusters attached by their oral hooks to the stomach lining. The maggots eventually detach themselves and are passed in the faeces on to the ground where, after undergoing a resting phase, or pupation, they emerge as adult insects. These are rather bee-like, but possess only one pair of wings, and vestigial mouth parts; they do not feed. The fly lays its eggs on the hairs of the zebra. These are removed by the tongue of the zebra while grooming itself, hatch in its mouth and then travel to the stomach where they attach themselves to the stomach lining.

Large numbers of bot-fly maggots are considered to produce debility in horses and it is also possible that the umbilicated ulcers produced by the oral hooks (Plate II, fig. (*b*)) interfere with digestion.

Large Intestine.—The contents of this organ in a freshly killed zebra frequently appear to be largely composed of a seething mass of small white worms named *Crossocephalus zebrae.* The sizes range from 1 to 5 mm. and males, females and larvae may be distinguished under the microscope. It is possible that this species is one of the very few helminths which is able to multiply within the body of the host. We have estimated as many as four million of these worms in the large intestine of a single zebra; this appeared to be in excellent health and it is probable that the parasite is relatively non-pathogenic.

When the intestinal contents are washed out, numbers of relatively large stout greyish worms up to 5 cm. in length may be seen firmly attached by their mouth to the intestinal wall. The majority belong to the genus *Strongylus;* their eggs are passed in the faeces and develop into infective larvae on the herbage within one week. Whe ingested by a susceptible zebra these larvae pass to the intestine; thereafter their development is unknown, although by analogy with related species in the horse, the larvae are ingested and pass to the intestine. Thereafter they penetrate the intestine and spend some time migrating in the peritoneal cavity before returning to the large intestine and maturing. One of the *Strongylus* species in the horse is frequently associated with colic or even death in young horses; the larval forms, while migrating in the peritoneal cavity, may produce sac-like lesions (aneurysms) of the abdominal arteries and these may cause pain, or, if they rupture, sudden death. These lesions have also been recorded in the zebra. In addition, one species, *Strongylus asini,* may be found in encapsulated cavities in the substance of the liver. We have seen considerable numbers of these lesions in the livers in two out of four zebra shot in the Kajiado area; these lesions were up to 2 cm. in diameter and whitish-yellow in colour. When the cyst wall was incised, the reddish-brown fluid content oozed out and apparently mature specimens of the worms were observed coiled in the cavity. It is possible that these lesions, which have been recorded as the cause of death in a Grevy's zebra in Chicago Zoo, are similar to the aneurysms described in horses and zebra.

Usually tapeworms are present also in the large intestine. They are usually about 10 cm. long and about 3 cm. wide at the base (Plate I, fig. (*a*)). The body is composed of a large number of segments which are extremely wide in relation to their length and tapers towards the head on which four small suckers may be distinguished. At the junction of head and body are four small flaps or lappets. The tapeworms belong to the genus *Anaplocephala,* and appear identical to those found in horses. In the horse, and presumably also in the zebra, the tapeworm's eggs are passed in the faeces and for the life-cycle to continue must apparently be eaten by small mites living in the grass. When this occurs the tapeworm egg hatches and the embryo encysts in the body of the mite; if the mite is later swallowed by a grazing zebra the tapeworm embyro is digested from the cyst, attaches itself to the wall of the large intestine and grows to maturity.

WILDEBEEST (*Gorgon taurinus*)

Rumen (First Stomach).—Pink or red worms (Plate II, fig. (*a*)) may be found lightly adherent to the lining of the rumen, particularly at the junction of the rumen and reticulum (second stomach). These parasites, of the family *Paramphistomidae* ("stomach-flukes") range from 2 to 8 mm. in length, are circular in cross-section and taper at both extremities. Unless present in large numbers they are not pathogenic. The worms are hermaphrodites and lay eggs which are passed out in the faeces. These hatch and the emergent larvae or miracidia must infect certain species of snails for the life-cycle to continue. The parasites multiply in the snail tissues and some weeks later emerge as small dark cercariae just visible to the naked eye. These encyst on herbage and no further development occurs until swallowed by a suitable host.

Abomasum (Fourth Stomach).—Often present on the inner surface of the abomasum are considerable numbers of the roundworm *Haemonchus contortus.* Each is about 2 cm. long and examined when fresh resembles a minute barber's pole, being transversely marked with red and white stripes (Plate III, fig. (*a*)). This is because the gut of the worm which runs the entire length of the body, is filled with blood, and the whitish reproductive organs are wound in a continuous spiral around the gut. The females, which are larger and thicker than the males, are prolific egg-layers, each producing 5,000 to 10,000 eggs

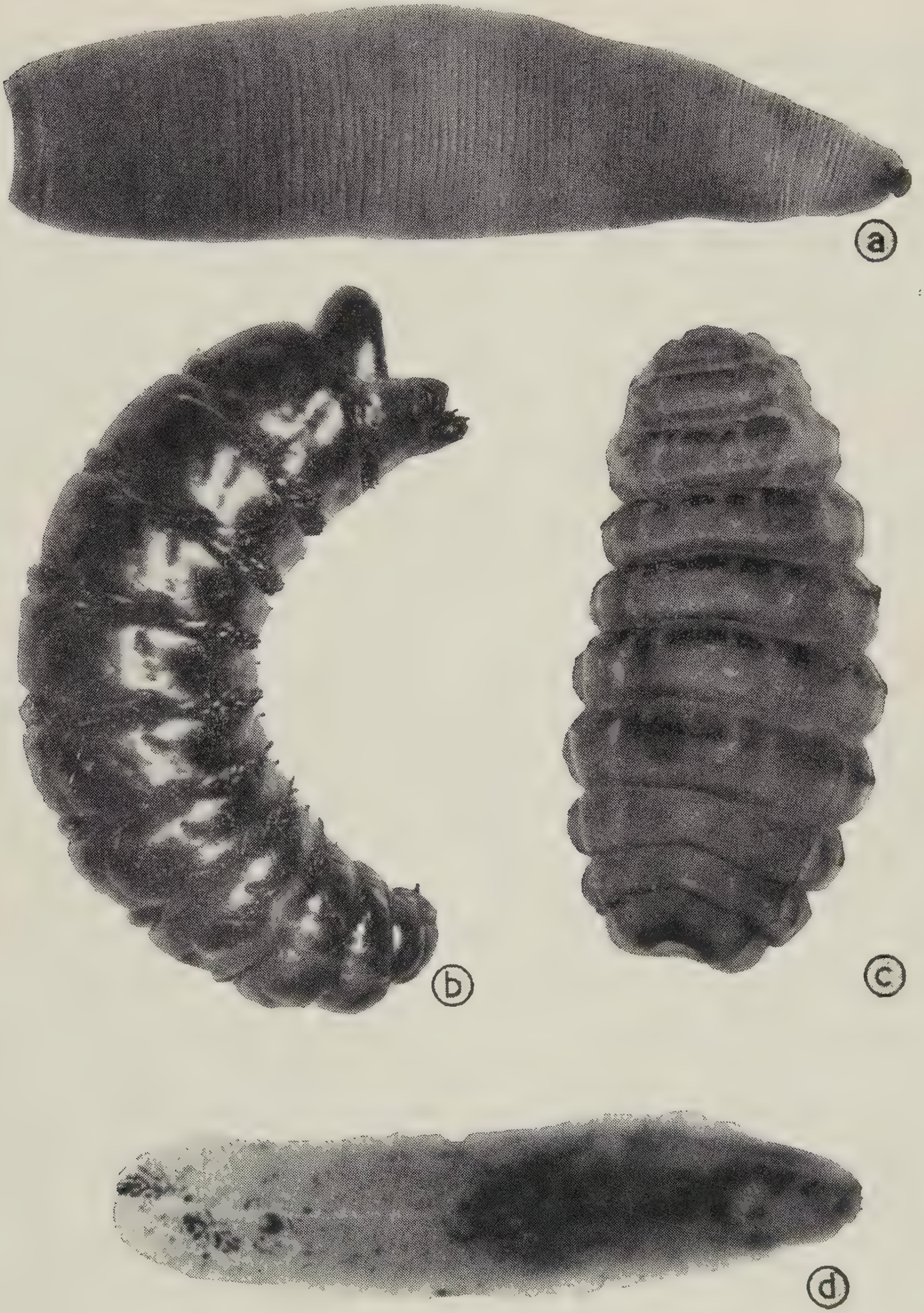

Plate I

(a) Tapeworm from large intestine of zebra.

(b) *Oestrus* **larvae from frontal sinus of wildebeest.**

(c) "Warble-fly" larvae from subcutaneous tissue of Grant's gazelle.

(d) *Fasciola gigantica* **from bile-duct of wildebeest.**

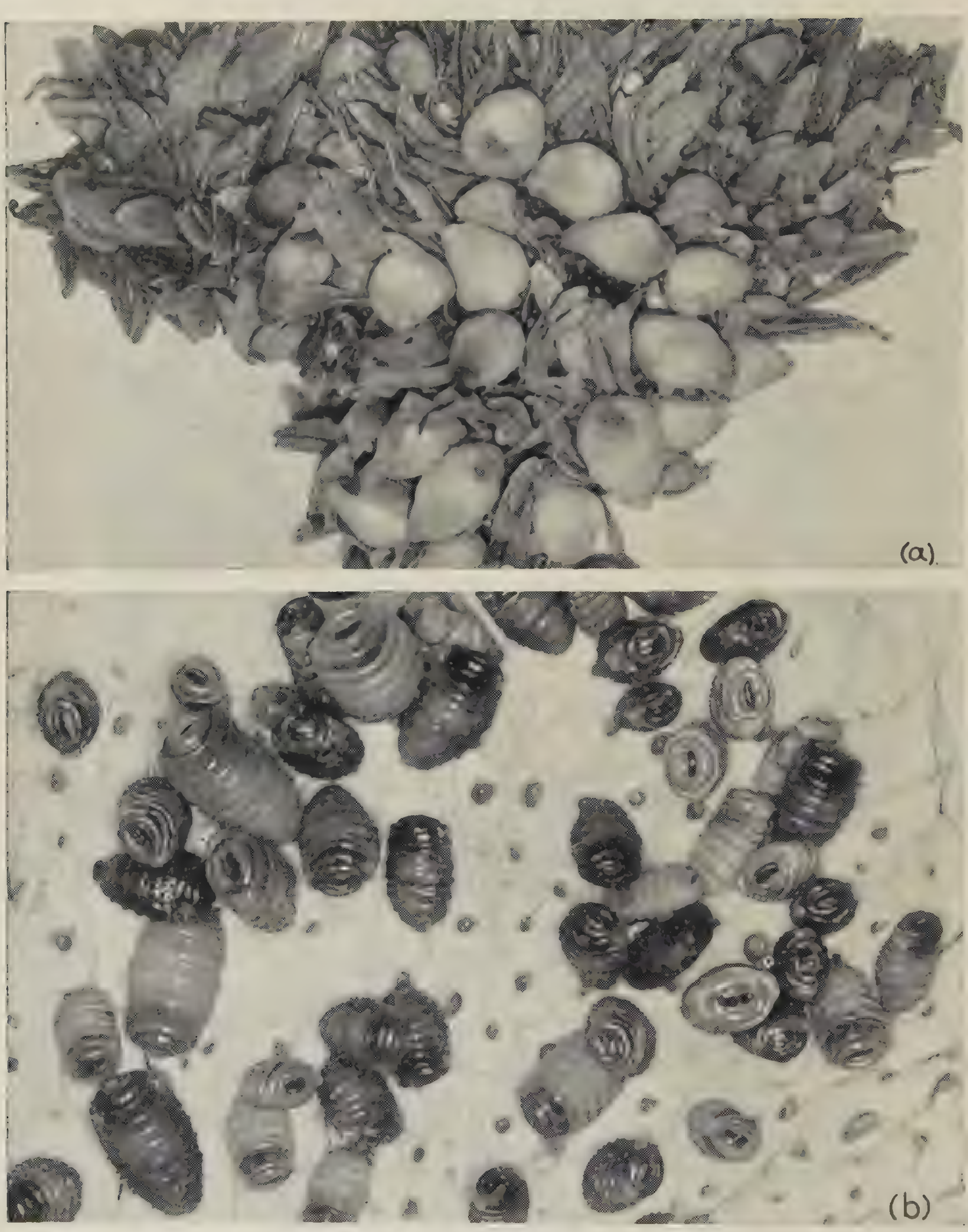

Plate II

(a) Paramphistomes attached to rumen of wildebeest.

(b) *Gastrophilus* **larvae attached to stomach of zebra.**

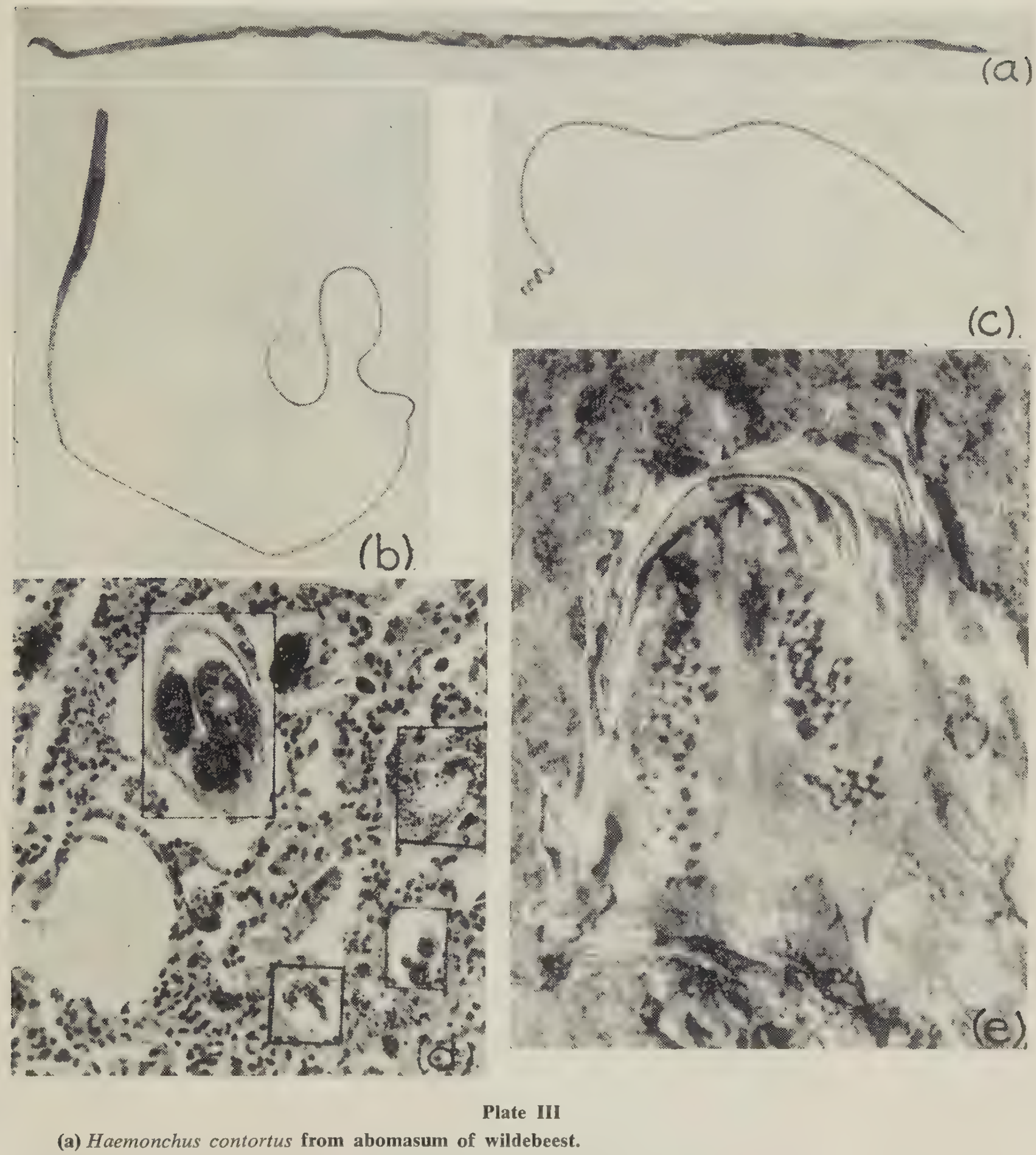

Plate III

(a) *Haemonchus contortus* **from abomasum of wildebeest.**

(b) *Trichuris* **("whipworm") from caecum of Grant's gazelle.**

(c) *Setaria* **from peritoneal cavity of zebra.**

(d) Photomicrograph of section of wildebeest lung showing adult lungworm and larvae trapped in alveoli.

(e) Numbers of "warble-fly" larvae attached to under-surface of skin of Grant's gazelle.

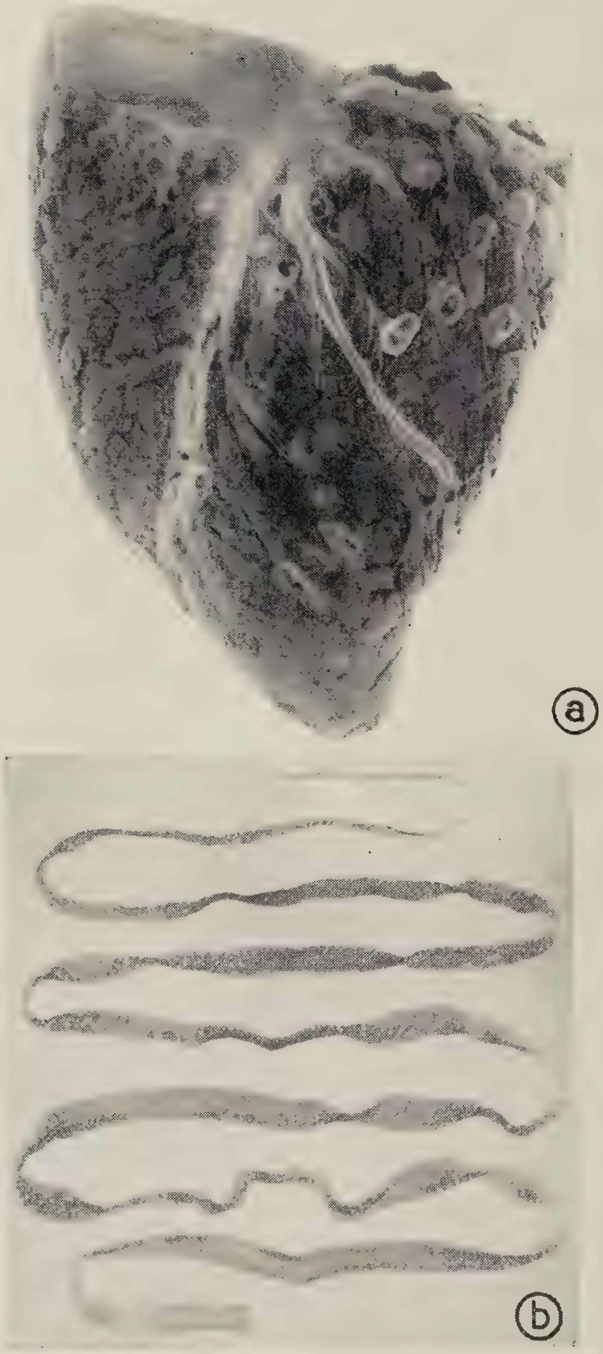

Plate IV

(a) Cysticerci on heart muscle.

(b) Tapeworm from small intestine of wildebeest.

daily. These are passed out in the faeces, hatch and develop into infective larvae within four or five days. The microscopic larvae climb on to the herbage and, if ingested by a suitable host, develop into adult worms in the host's stomach within three weeks. This species is well known as a voracious blood-sucker and, if present in sufficient numbers, can quickly kill sheep and cattle. It must not be assumed, however, that the *Haemonchus* found in wildebeest will necessarily infect sheep and cattle. Indeed, sheep and cattle each have their own sub-species of this parasite and these do not normally cross-infect. Furthermore, preliminary results from some experimental work in progress at the East African Veterinary Research Organization have indicated that *Haemonchus* from wildebeest do not infect bovine calves.

Small and Large Intestines.—Small raised nodules, about 5 mm. in diameter, may be seen on the inner surface of the intestines. Each is caused by the developmental stage of a larva of the nematode *Oesophagostomum*. The infective larvae of this species burrow into the mucosa of the intestine and may remain there for several months before re-emerging to grow adult. The host may react violently to their presence and each nodule represents an attempt, often successful, to wall off and destroy the larvae. The adults resemble *Haemonchus* in their gross appearance, but are only found in the large intestine. A similar parasite is found in sheep and is of little significance when present in small numbers; large numbers, however, cause severe diarrhoea, often terminating in death.

Again from work in progress at the East African Veterinary Research Organization, it appears that *Oesophagostomum* larvae from wildebeest do not infect cattle.

Another worm found in the large intestine is *Agriostomum*. This grossly resembles *Oesophagostomum* but is usually attached by its head end to the mucosa and is brownish in colour. *Oesophagostomum* lies free in the lumen of the intestine and is white. The pathogenicity of this parasite, a true hookworm, in East African wildebeest is unknown, but since each worm possesses four pairs of large teeth and almost certainly subsists by blood-sucking it is possible that large numbers would cause weakness and anaemia.

Tapeworms about 50 cm. long may be found in the small intestine. They belong to the family *Anaplocephalidae* and their life-cycle is similar to that described for *Anaplocephala* in the large intestine of the zebra.

Liver.—Leaf-shaped worms about 3 cm. long are frequently found in the lumina of the bile-ducts. They are *Fasciola gigantica*, the giant liver-fluke (Plate I, fig. (*d*)). The colour is usually greyish with black mottling, the latter caused by the presence of altered blood in the branching gut of the parasite.

The worm is widely distributed in domestic and game animals in Africa. Large numbers in the liver may cause death, but light infestations usually associated with thickening of the bile-duct walls are more common.

The life-cycle is similar to that described for the *Paramphistomidae* found in the rumen, except that the cercariae are whitish in colour.

Lungs.—In the trachea and bronchi, lungworms of the genus *Dictyocaulus* may be found. These are white nematodes about 5 cm. long and are most frequently present at the terminus of the main branch of each diaphragmatic lobe. Minute larvae are laid by the female and these are coughed up, swallowed, and passed out in the faeces of the host. They leave the faeces and migrate on to the grass. If swallowed by a suitable host the larvae penetrate the intestine and reach the lungs via the bloodstream, where they grow to maturity in about four weeks. In temperate countries a related parasite is a frequent cause of pneumonia and death in calves and cattle. It has been described from the higher and wetter parts of Kenya, but is not usually responsible for clinical disease. The lungworm infections which were observed in wildebeest were all light infections and were chiefly interesting in showing that the larval stages of at least one species of *Dictyocaulus* has apparently adapted itself to survival in plains which are often hot and dry.

Circumscribed raised greenish-yellow lesions about 2 to 4 cm. in diameter may be observed on the surface or in the substance of any part of the lungs. These are relatively solid and when squeezed the cut surface may exude a whitish fluid. When these lesions are sectioned, stained and examined microscopically, small adult lungworms may be observed in the finer respiratory passages. Surrounding these worms are large numbers of larvae trapped in the terminal air passages or alveoli (Plate III, fig. (*d*)). The presence of large numbers of these parasites and the accompanying inflammatory reaction of the host are responsible for the gross lesions described above. The most probable explanation for the production of this lesion is that the larvae laid by the adult female worms, instead of being coughed up, are aspirated into the terminal air passages during the inspiratory gasp preceding a cough. Once in this site they become trapped by the cellular response of the host. The small worms responsible for these lesions have not been identified.

Muscles.—Small whitish cysts about the size of a pea may be frequently observed in the skeletal muscles, and in the heart and tongue (Plate IV, fig. (*a*)). Each cyst consists of a thin fibrous capsule produced by the host and surrounding a tapeworm cyst or cysticercus. This consists of a small bladder filled with clear fluid and containing a white spot, the head of the future tapeworm. The parasite is the intermediate stage of a *Taenia* tapeworm and its counterpart in cattle is the cause of considerable expense to the meat industry in Kenya. It must be noted, however, that all the cysts which we have examined from wildebeest were of a different species from those found in cattle in that the head of the cysticercus possessed two rows of hooks and four suckers, while the cattle parasite has four suckers only. The final host, i.e. the host in whose intestine the tapeworm grows to maturity, is probably the hyena or jackal or, less likely, the lion or leopard. The adult tapeworm lays eggs which are passed out with the faeces of the final host on to the pasture. These in turn are ingested by susceptible wildebeest, the eggs hatch and the embryos penetrate the intestine and encyst in the muscles.

Nasal Cavity and Frontal Sinus.—In all the wildebeest which we have examined the nasal cavity and frontal and horn sinuses contained maggots of the genus *Oestrus*. These (Plate I, fig. (*b*)) range from 6 to 20 mm. in length and are segmented. The pointed anterior end has small black hooks and the blunt posterior end has a characteristic stepped appearance and possesses two black spots, the stigmatal plates, through which the maggot respires. The maggots hatch from eggs in the nostrils laid by a species of *Oestrus* and migrate up the nasal cavity into the sinuses. After some time, as yet unknown, the maggots return to the nasal cavity and are sneezed out on to the ground. There they undergo a resting phase, or pupation, eventually emerging as adult flies. The flies belong to the same family as the *Gastrophilus* described earlier which parasitizes the zebra. The clinical significance of the maggots in the sinuses is unknown.

One interesting point is that in several of these wildebeest we have observed considerable numbers of minute maggots about 2 mm. long in the cranial cavity on the surface of the meninges of the brain. They appear to be the first stage of the large maggots observed in the sinuses and nasal cavity. It is usually accepted that *Oestrus* larvae which are very common in sheep and goats do not normally parasitize the cranial cavity, one authoritative text stating that contrary to popular belief it is impossible for them to enter the brain cavity. It is, therefore, odd that numbers of these small larvae should have been observed in the cranial cavity of four out of five wildebeest examined consecutively, and this observation merits further study.

GRANT'S GAZELLE (*Gazella granti*)

Abomasum.—*Haemonchus*, described earlier, earlier, is commonly found.

Large Intestine.—Slender worms about 7.5 cm. long and bearing a marked resemblance to a stockwhip are found in the caecum, or blind sac of the large intestine (Plate III, fig. (*b*)). The thick "handle" is the posterior end of the worm, the tapering anterior part containing the long oesophagus. These belong to the genus *Trichuris* ("whipworms").

Lungs.—These frequently show the greenish-yellow lesions containing small lungworms and larvae which were described in wildebeest.

Muscles.—Measles cysts, similar to those described in the wildebeest, are commonly found in Grant's gazelle. These, however, must not be confused with the whitish spindle-shaped lesions varying from 1 to 6 mm. in size which are frequently present in considerable numbers in the muscles. Apart from size and shape these lesions do not contain a bladderworm but, when cut, exude a whitish paste. If smears made of this substance are stained and examined microscopically, they will be found to contain masses of small spores. These lesions appear to be sarcocysts and consist essentially of small sacs filled with packed masses of spores. Very little is known of these parasites and it is not even certain whether they are protozoal or fungal in origin. They are non-pathogenic.

Skin.—Inspection of a young male Grant's gazelle shot by one of us in September, 1959, revealed large numbers of small lumps under the skin on either side of the spine. These could be recognized several yards away by the disturbed hair pattern above each lump. Each lesion was caused by a large larva lying below and adherent to the skin. Approximately 100 larvae were present (Plate III, fig. (*e*)); each was about 2.5 cm. long, yellowish to brown and segmented. All but the last three segments possessed a transverse pad of small spines. (Plate I, fig. (*c*)). The posterior end of each larva, carrying the respiratory pores, pointed toward the skin surface and in some of the lesions protruded slightly through the skin.

As far as we can ascertain this is the first record of "warble fly" in indigenous cloven-hoofed animals in East Africa. The larvae belong, or are related, to the genus *Hypoderma* and are similar to the *Gastrophilus* and *Oestrus* species described earlier. The female fly cements its eggs on to the hairs of the host. Larvae hatch from the eggs, move down the hair and penetrate the skin. They spend several months migrating through the muscles of the host and eventually reach the subcutaneous tissue on either side of the back. The larvae spend some time here, finally emerging and dropping to the ground. Pupation takes several weeks.

The larvae of two species of *Hypoderma* are commonly found in cattle in Europe and America. They are of great economic importance as the damaged hides, holed and thinned by the penetration of the larvae, cost the livestock industry many thousands of pounds yearly. Lewis (1933) noted that cattle imported into Kenya from Britain had been observed at the quarantine station to harbour *Hypoderma* larvae. No evidence that the adult flies existed in Kenya was available and he concluded that conditions were unfavourable for their development.

We should be interested to learn whether or not any reader has observed similar larvae in East African gazelle, as it may establish whether or not the parasite is of recent origin. There is no evidence at all to suggest that this species may infect domestic cattle.

THOMSON'S GAZELLE (*Gazella thomsoni*)

Peritoneal Cavity.—When removing the abdominal viscera clear cysts about 2 to 4 cm. in diameter may be observed loosely attached to the peritonial covering of the liver or in the folds of the mesentery. If these are lightly cut the cysts may be squeezed from their peritoneal sheaths. This bladderworm is similar in appearance, although much larger, to the cysticercus described in the muscles of the wildebeest. The parasite *Cysticercus tenuicollis* is common in sheep and cattle. The final host is the dog and, presumably, also the hyena and jackal, which acquire the tapeworm by eating infected viscera.

Abomasum.—In addition to *Haemonchus contortus,* described earlier, there may be observed on the mucosa or in nodules on the wall of the abomasum numbers of white nematodes 20 to 50 mm. long. This parasite, *Gazellostrongylus lerouxi,* was described and named for the first time by Yeh in 1956. Nothing is known of the life-cycle. We have observed these nematodes also in the abomasum of the Grant's gazelle lying free and in nodules.

Caecum.—Whipworms similar to those described in the Grant's gazelle are usually found.

Lungs.—Greenish-yellow lesions similar to those in wildebeest and Grant's gazelle and containing small worms are common. Although the species is not known, small lungworms have been described from the lungs of this animal by Yeh (1956) and named *Protostrongylus gazellae.* It is possible that these are the same parasites.

Muscles.—Small cysticerci similar to those in wildebeest and Grant's gazelle are found.

COLLECTION AND PRESERVATION OF PARASITES

Although detailed description of the morphology of parasites is essentially a specialist affair, the collection and preservation of parasites can be undertaken by any interested person. A small booklet "Instructions for the Collection of Parasites and other material from Game Animals" was prepared by the staff of the East African Veterinary Research Organization at the request of the 1958 British East Africa Fauna Conference and copies may be obtained by writing to the Director.

It is most important that any preserved specimens have an attached label stating:—

(*a*) Host animal.

(*b*) Locality and date of collection.

(*c*) Organ from which parasites were collected.

Additional information, e.g. free in bile-duct, nodule on outer wall of small intestine, free in lumen of abomasum, is also very useful.

(*d*) Name of collector.

The authors would be very pleased to receive such material.

DISCUSSION

Apart from systematics, our knowledge of the biology and significance of the internal parasites of game is almost non-existent and presents a fascinating field of study. One wonders, for instance, whether the migration of certain species of game may be stimulated by incipient parasitic gastro-enteritis or by the irritation occasioned by large numbers of Oestrid flies. It is also possible that the restriction of game animals to parks or confined areas may, if these are too small, lead to a build-up of parasitism, disease and death.

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REVIEW

BEEF CATTLE HUSBANDRY, by Allan Fraser, Second Edition (Revised), published by Crosby Lockwood, London, 1959, pp. 241, figs. 66, price Sh. 21.

Dr. Allan Fraser, as past hordes of students will confirm, has a suspicious nature where things scientific are concerned. As a result, his writings are valuable, in that new views and ideas are carefully digested before conclusions are reached and hence his books are invariably reliable. Having achieved renown as a "scientific shepherd" it is perhaps a little surprising that Dr. Fraser has turned his authoritative pen to beef husbandry with such ease.

The book is as readable as a novel and it maintains the Fraser reputation of wit and barbed statements. It has 16 chapters including two entirely new chapters on "Some Foreign Breeds" and "Recent Scientific Development". The major beef breeds merit a chapter each and Dr. Fraser traces their history to the present day. History need not be dull and the text is full of amusing anecdotes to prove this point. One example "Bates was a very pious person—he was, in fact, nicknamed 'Bible Bates', but he never learnt to love his neighbour's cattle as his own."

Also included are sections on hill cattle, dairy culls as beef, cattle rearing and veal and baby beef production. The chapters on fattening are characteristic of the book—a skilful blend of history, profitable practices and relevant experimental data.

Until quite recently beef husbandry has escaped the searching eye of science but now with momentum building up it is essential that a volume containing traditional beef husbandry knowledge along with the newer scientific information be available. Dr. Fraser has successfully blended the old and new in such a volume "Beef Cattle Husbandry". It can be heartily recommended to all beef producers throughout the world.

H. G. L.

THE GROSS ENERGY CONTENT OF SOME KENYA FEEDS

By H. W. Dougall, Grassland Research Station, Department of Agriculture, Kitale, Kenya

(Received for publication on 23rd December, 1959)

When the value of a feeding stuff is to be assessed from the standpoint of its value for heat production, the first step in such an evaluation is to measure the gross amount of heat which the organic components of that feed can produce when completely burned. The necessary measurements are obtained by the use of a bomb calorimeter.

The procedure involved has been used to determine the gross energy contained in two grasses, two cereals and a legume grown at Kitale and sampled at weekly intervals in order to take into account the effect, if any, of their maturation. It has also been used to determine the gross energy contained in 50 different grasses growing in the nursery and sampled when they each had reached the early flowering stage of growth. The results of these determinations are tabulated together with those reported by Walker and Hepburn [1955, 1956] for hays and silages examined by them in Scotland. The hays were composed of grass/legume mixtures cut at the "bloom" or "pre-bloom" stage of growth. The silages were "in all cases prepared from grassland herbage varying in composition from simple seeds mixtures of rye grass and red clover to the more complex botanical mixtures obtained from older leys or permanent pastures. The stage of growth of the grass varied from a wholly leafy mixture to mature herbage intended for hay and well past the flowering stage". Molasses was added to some of the early-cut grass during ensiling.

It is apparent from these data that the gross energy contained in the grasses, cereals and legume which were sampled at advancing stages to maturity, is remarkably constant for each of the species concerned. This result would seem to imply that "stage of growth" can have but little influence on the gross energy per unit weight of plant material. Similarly, for the 50 nursery grasses which were sampled at the early flowering stage of growth, gross energy is remarkably constant, as is also the case of the Scottish grass/legume hays which were cut at the "bloom" or "pre-bloom" stage. The gross energy contained in the Scottish silages is less constant, but not unreasonably so, bearing in mind the heterogeneity of the materials used and the inclusion or omission of molasses during silage making.

There are, of course, differences between individual feeds, as for example between the Scottish hays and the Kitale nursery grasses and the Kitale lucerne and the Scottish hays. These differences, though relatively small, achieve statistical significance. From the standpoint of energy utilization by farm animals—the so-called "gross digestible energy"—the differences reported here may not be very important.

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Feeding Stuff	Source	Number of Samples	Stage of Growth	Gross Energy (kg-cal/g)	S.E.
Lucerne	Kitale	9	Advancing stages of growth from young material to complete maturity.	4·58	0·014
Wheat	"	17		4·35	0·041
Barley	"	17		4·36	0·019
Hyparrhenia dissoluta . .	"	10		4·15	0·021
Cynodon dactylon:—					
1st Series	"	15		4·23	0·017
2nd Series	"	10		4·15	0·027
Nursery grasses	"	50	Early flowering.	4·24	0·018
Hays	Scotland	24	"Bloom" or "pre-bloom".	4·41	0·014
Silages	"	24	Wholly leafy to mature herbage.	4·58	0·265

SHINYANGA: A REVIEW OF THE WORK OF THE TSETSE RESEARCH LABORATORY*

By J. P. Glasgow, East African Trypanosomiasis Research Organization, Tororo, Uganda

(*Received for publication on 20th January, 1960*)

At the end of the first World War the importance of tsetse-flies in denying large areas of Africa to human use was clearly realized, but the only method of control which had been suggested was game destruction. C. F. M. Swynnerton was Tanganyika's first Game Warden, and as more than half the territory was occupied by tsetse (Potts, 1937, put the figure between two-thirds and three-quarters) Swynnerton saw, in the possibility that game destruction might become the anti-tsetse measure of official policy, a serious threat to the territory's game animals. He was not a stranger to tsetse work, having already in 1918 carried out an investigation of the habits and distribution of tsetse-flies in the northern portion of the Mossurise District, Portuguese East Africa, for the Mozambique Company (Swynnerton, 1921). He made a survey of tsetse distribution in Tanganyika in 1921. His map was not published at the time, but was incorporated in the map published by Potts in 1937.

Swynnerton, who was a farmer before he was a Game Warden, saw the trypanosomiasis problem not merely as another disease, but broadly, as a matter of land usage. This outlook was made clear in a Game Circular entitled "Tsetse Control" and issued in August, 1921. This deals mainly with the advantages of postponing grass fires till late in the dry season so that they may be as fierce as possible and control "vile thicket", tsetse bush, and ticks. This circular is reproduced as the Appendix, not only because of its great historical interest but also because it contains much excellent advice as relevant now as it was 40 years ago. It is also a rare document, the only known extant copy being in our library. With the publication of the circular, "late burning" became the official policy in Tanganyika. That it was widely implemented may be doubted, but it was introduced into Shinyanga with very gratifying results. At this time the sultanate, as it was then called, of Shinyanga was suffering rapid depopulation. The causes of the beginning of the depopulation are somewhat obscure, raids by Mirambo from Tabora, local fighting and epidemics being all mentioned as possible factors. About 1912, however, tsetse (*Glossina swynnertoni* Austen) appeared in the bush regenerating on the abandoned cultivation. The resultant losses of stock induced further depopulation, followed by further upgrowth of bush, and so on, until by 1921 it was estimated that 30,000 people had left the chiefdom, and only three or four thousand remained. The following is the account given by Swynnerton (1936) of subsequent events.

"In 1922, I decided that if support were forthcoming, I would attempt a large-scale experimental attack on a tsetse situation with a view to applying such knowledge and ideas as were already available, to gaining further experience and especially to learning what practical difficulties faced us and should be investigated. It was hoped that a special team for research and reclamation combined might be provided later. I was begged by the Senior Commissioner, Tabora, Mr. H. C. Stiebel, to locate this attack in Shinyanga in view of the seriousness of the situation in that area.

"The Colonial Office at this stage invited proposals and the scheme just referred to was sanctioned.

"Detailed exploratory surveys were carried out and Shinyanga was actually chosen as the site of operations. It was decided to attempt at the outset to ascertain (i) whether an annual voluntary out turn of a native population could be organized to attack their own problems; (ii) whether natives could be persuaded to settle in places in which their presence would consolidate gains made or assist in making them; and (iii) whether by postponing and organizing the annual grass-fires tsetses could be driven from good grass country.

"The chiefs and people responded splendidly and, after a small preliminary beginning in November, 1923, 10,000 men came out from the chiefdoms generally and worked for a month in 1924 under the guidance and supervision of Mr. S. P. Teare (Game Ranger), myself, and our game scouts. They placed a cleared barrier in front of the fly advance which, with settlement behind it and organized grass-fires within it, it has never since passed; they made a great 24-square mile clearing in the piece of country (Kizumbi) that still retained some little settlement, with a view to turning the tide; they made a beginning with a scheme of splitting up the fly belt into blocks in which different measures could be tried out and the clearings between which would hinder the return of the flies into any block from which they might have been driven; and some of the contingents did work as well in their own special sections of the district.

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* Contributed on the occasion of the laboratory closing.

"Settlers began to enter the district in 1923 and this influx gradually overtook and outstripped emigration. Inducements were given including an acre plot annually in a large cotton field, which after having personally trained the oxen and drivers, we ploughed, and which has since been transferred from the Tsetse Research Department to the Department of Agriculture and is today the important Lubaga Agricultural Station. Many of the younger new settlers were taught later by Mr. Teare to plough and took to it keenly. The first instalment of the controlled grass-burning campaign took place in 1924, and, in a country then swarming with tsetse, produced spectacular effects."

This work was organized by the Game Preservation Department consisting in 1924 of the Director (C. F. M. Swynnerton) and four Game Rangers. The first specifically tsetse staff came in 1925. The success of the 1924 operations had considerably eased the Shinyanga position and for a few years work was centred on an urgent situation in the Kondoa Irangi District. The Department did not lose touch with Shinyanga, but little intensive work was done.

At the beginning of April, 1929, the Department of Tsetse Research achieved formal separation from the Game Preservation Department, Swynnerton becoming the first Director and accepting a 20 per cent reduction in salary (from £1,500 to £1,200 p.a.) to do so. He moved from Kilosa, then the headquarters of the Game Department, and set up his new headquarters at Kondoa. The European establishment of the new Department was 14—Director, Deputy Director, two Entomologists, two Botanists, two Zoologists, Secretary-Librarian, four Observers and a Reclamation Officer. These posts cannot be translated exactly into modern nomenclature; the entomologists, botanists and zoologists would now all be called Research Officers and the reclamation officer would be a Field Officer. The Observers, however, came in between; all holders of the posts in 1929 had university degrees or diplomas.

The setting-up of the new Tsetse Research Department coincided with a somewhat artificial separation of "Tsetse Reclamation" which became the responsibility of the Provincial Administration, and "Tsetse Research" carried out by the new Department. This separation was not satisfactory and did not last after 1930. It never could be satisfactory until reclamation methods were available which could be described as thoroughly reliable and not in any sense experimental. This is perhaps an appropriate point to trace briefly the subsequent history of reunion and schism between tsetse research and tsetse reclamation. In 1931, reclamation became once more the responsibility of the Tsetse Research Department. It continued to be so until at the time of the Department's greatest expansion in 1946 it was running schemes of experimental reclamation in Kenya, Uganda and Northern Rhodesia, besides several in Tanganyika itself. Then in 1948 came the greatest schism, Tanganyika set up its Department of Tsetse Survey and Reclamation with headquarters in Arusha, the East Africa Tsetse Reclamation Department was set up with headquarters in Nairobi, charged with the conduct of experimental reclamation, and Shinyanga was left alone to do pure research. A year later, however, the Shinyanga laboratory, the E.A. Tsetse Reclamation Department, and the Tinde Sleeping Sickness Laboratory were united in the clumsily named East African Tsetse and Trypanosomiasis Research and Reclamation Organization. When reclamation and research into tsetse biology are prosecuted hand in hand, it has been found that the research suffers because the reclamation is politically more urgent and cannot brook the delays essential for exact scientific observation. Yet complete divorce seems not entirely satisfactory, as evidenced by the existence of research activity in Departments which exist to carry out tsetse control.

After this diversion we may return to consideration of the Department at Shinyanga in 1930. When the railway reached Shinyanga in 1928 the station was built, for technical reasons, nine miles from the town. The Administrative station was thereupon moved to a site near the railway station and the town of New Shinyanga grew up there. When the Tsetse Research Department moved its headquarters to Shinyanga in 1930 it was able to occupy the vacant buildings, of which the most important was the German fort which had been built in 1912. New Shinyanga was built in Block 1, the first of the blocks which had been isolated for piecemeal treatment, and we may presume that it was free of tsetse by 1930. The situation in the rest of the district is best summarized by a further quotation from Swynnerton (1936).

"The return of our headquarters to Shinyanga has given a new lease of life to our original scheme of reclamation-experimental and tribal, combined in a productive co-operative effort. After the great initial attack on the western Shinyanga problem in 1923-24 it was ruled that each chief's annual contingent should so far as possible work only in that chief's area. The campaign for the expulsion of the fly came to depend on some small contribution in labour each year for a scheme which had been intended (i) to provide methods for the use of all chiefdoms, and (ii) by providing large new areas for grazing to relieve the heavy over-grazing and erosion taking place in the whole settled area. The tribal effort became dissipated annually in a series of small and widely separated local clearings, some of them of little real use, many of them poorly executed. The central scheme thus became rather disorganized. The arrival of our headquarters and an adequate staff in Shinyanga, the energetic prosecution of anti-tsetse measures by ourselves with some money to spend on it, the backing of a keen administration and the revival of interest which was added to by our being able to hand back to this section of the tribe in 1932, Chibe, its traditional birthplace, which had been lost to the flies many years earlier, gave new impetus and quality to the work. Further, a middle path seemed suggested whereby, while retaining popularity for the work by catering for local wishes, such parts of the central scheme as would especially interest a chiefdom were allotted to it to carry out. But whereas in the beginning all the work was experimental, including the employment of the tribe, today no tribal labour is employed on experimental work."

By consolidating existing gaps in the bush the country was split into blocks, varying from four to a hundred square miles, which could be treated one by one by a variety of methods. In 1930, late burning was still the most important weapon, and it was found to have at least two important effects. The long-term effect, apparent after four or five good burns, was to open the country up, by destruction of thicket and smaller trees, to a point at which it was quite incapable of supporting *G. swynnertoni* or any other tsetse. This effect, of course, was cumulative, since the less woody cover the better the grass growth and hence the better the next burn. But more immediately, the long walls of flames drove the tsetse before them (many, we may surmise, died of exhaustion) and they became concentrated in a few restricted places which for one reason or another had not burned. These concentrations of tsetse were attacked by intensive hand catching for a few days immediately after the burn. Large numbers were caught in this way, which was thought to contribute to the rapid decreases observed and must have been an impressive experience for the local Africans taking part.

During the '30s, the most important field experiment undertaken at Shinyanga was the total exclusion of fire from areas which were continually increased. The experiment had been projected for some years, ever since, in 1925, it had been demostrated that the Itigi Thicket vegetation of the Central Province excluded *G. morsitans* Westwood although surrounded by *Brachystegia* woodland in which this tsetse was common. In 1929, fire was excluded from a strip of woodland in Shinyanga, in an attempt to make a dense belt, impenetrable to *G. swynnertoni*, which would be a barrier to that tsetse. The following year a block of four square miles was put under fire exclusion, and remained so for 20 years. Although fire exclusion is the exact opposite of organized late burning, much of the work involved is the same in both cases. The organization involved in late burning—making firebreaks at the end of the rains, posting firewatchers, and having a "fire-brigade" to put out accidental fires—was all repeated for non-burning with the sole difference that the organization was continued until the beginning of the next rains. In both cases an absolute essential was the willing co-operation of the African public.

In the first year of non-burning, that is some 18 months after the last fire, there was a noticeable increase of woody growth, but the most striking vegetational effect was that the young grass was coming up through a mat of old dead recumbent grass. No effect on the game animals was noted at this stage, but there was an effect on the tsetse, which fell in numbers during the dry season (regarded as normal) but failed to recover during the subsequent rains. After three or four years extensive upgrowth of thicket occurred, and the bush as a whole appeared more uniform than before. In the hard-pan areas ("ibambasi" soils with impeded drainage) very little change was brought about by fire exclusion, since the grass growth on this soil type is so poor that there is almost nothing to burn. Longer and denser grasses were thought to be invading them from the edges, together with thicket of *Ormocarpum* and *Dichrostachys*, but the process, if indeed it occurred, was very slow. Coinciding with the change in vegetation, and presumably largely caused by it, was a change in the composition, but not in the volume, of the game population. Animals of the open country, such as impala, moved out of the unburnt area, while giraffe and greater kudu were favoured. Harrison (1939) noted that wart-hog, bush-pig and duiker were perfectly at home in the fire-exclusion area, although he did not venture an opinion as to whether their numbers had increased. After eight years *G. swynnertoni* was approaching extinction in Block 4, the area from which fire was first excluded, and extinction was actually achieved in this block during the war years. The process is reversible, however; Block 4 is now a Forest Reserve, not protected from fire, and *G. swynnertoni* is re-established in it in small numbers.

Swynnerton (1936; p. 274) and Potts (1939) discuss the mechanism whereby the effects of fire-exclusion on *G. swynnertoni* were brought about. The possible role of predators on adult tsetse is dismissed by Swynnerton with surprising curtness. "None of our observations suggests that birds or insects predatory on tsetse, or any fungus, have been at work." It was suggested that some interference with reproduction must be the explanation. Potts considered, firstly, whether the sexes were failing to meet, secondly whether enhanced humidity of air or soil might adversely affect either larviposition or pupal survival, and rejected both possibilities. He inclined to the view that fire-exclusion might be followed by greater loss of pupae by predation, but his conclusions were expressed in very general terms: "There is little doubt but that *G. swynnertoni*, and probably the other savanna tsetse *G. morsitans*, are both creations of that subclimax, savanna woodland, which is perpetuated and extended if not even initiated by man himself with his annual firing of the grass; the advancement of this subclimax to its natural climax by the release of the process of biotic succession gives rise to conditions which its creature, the savanna tsetse, cannot tolerate."

The early results of fire-exclusion were so promising that the measure was applied to increasingly large areas, totalling some 700 square miles by 1938. This had to be drastically curtailed during the War, since many of the staff joined the Forces. Block 4, however, the original block to be protected, which had been under fire-exclusion since 1930, was kept protected from fire, as was Block 11, from which fire was first excluded in 1933. In this Block *G. swynnertoni* was by 1937 reduced to a low figure, but further progress appeared to be slow, as it had been in Block 4. As the remaining flies appeared to be concentrated on the hard-pans, these were cleared, and *G. swynnertoni* disappeared. The total area cleared was only 5 per cent of the whole block, and the work was easy as hard-pans are only lightly wooded. The work of locating the hard-pans was expensive, involving very detailed ground reconnaissance, but in practice this can be avoided by the use of aerial photography.

Thus, by 1948, in addition to the original technique of late-burning, non-burning, and non-burning accelerated by discriminative clearing, had both been demonstrated to eliminate *G. swynnertoni*. Non-burning, however, although at first glance a cheap measure, is in fact an expensive one. The overheads involved are very large. The success of the original exclusion of fire from Block 4 was greatly helped by the proximity of the Block to the Old Shinyanga headquarters, where for many years there were standing orders to the effect that fire fighting had priority over all other activities. The magnitude of the overheads became apparent when the measure was extended to distant blocks out of range of headquarters, where special fire-exclusion staff had to be stationed. Moreover, the expenditure on fire-exclusion does not benefit the land, apart from its effect on tsetse. The grazing is impaired, the extra woody growth is a hindrance to cultivation and in fact the "vile thicket" of the 1921 circular is extended. Thus it was natural that the next step should be an attempt to do without fire-exclusion and to attack tsetse by discriminative clearing alone. This was not done in Shinyanga because by this time the schism already noted, between research and reclamation, had removed the responsibility for experimental reclamation from Shinyanga.

The writer is very conscious of the inadequacy of this account of fire-exclusion and discriminative clearing. Doubtless the ultimate cause of the disappearance of *G. swynnertoni* from these two blocks was fire-exclusion, accelerated in one case by clearing the hard-pans. What was the proximal, immediate cause? We still do not know.

This account of the fire-exclusion experiments has taken us past the great expansion of the Department in 1938. Previously expenditure was limited to £15,000 a year, of which £14,250 came from the Colonial Development Fund and the remainder from Tanganyika. In 1938 it was announced that the Colonial Development Fund would make a grant of £208,000, and Tanganyika would contribute £35,000, to be spread over seven years. The establishment of European officers was increased from 13 to 30. Less than three months later, before many of the new officers had arrived, Swynnerton was killed in a flying accident near Singida. He had been doing an aerial reconnaissance with the Department's botanist, B. D. Burtt, who was killed with him. This double tragedy was an irreparable loss to the Department. Swynnerton was one of the most remarkable men that Tanganyika has known, Burtt had been with him since 1925 and had acquired a very extensive knowledge of the Tanganyika flora. Little of his results was published during his life, but three posthumous works edited by his colleagues (Burtt, 1939, 1942 and 1953) have preserved much of his knowledge. The expansion of the Department continued, however, in accordance with the plans made by Swynnerton, and at the end of 1938 the Director of Veterinary Services, Mr. H. E. Hornby, became the new Director. In the middle of 1939, just before the outbreak of war, there were 26 European Officers in the Department, of whom 13 were at Old Shinyanga, four at out-stations in the district, six elsewhere in Tanganyika, two in Kenya and one in Northern Rhodesia. The war, of course necessitated very great curtailment of these activities, but many of the plans, or developments of them, were carried through in the immediate post-war years.

Since the Department of Tsetse Research evolved from a Game Department one would expect game-fly relations to receive considerable attention, and this has in fact been so. Swynnerton intended to conduct a game experiment from the beginning, and one of the Shinyanga blocks (Block 9) was from an early date reserved for the work. It was recognized to be a long project, however, and there was a reluctance to embark on it in the early hand-to-mouth days of the Department. It was not until 1934 that there was sufficient confidence in the future of the Department to make a start. The early thinking on the subject was, naturally severely practical. The observed paradox that a small game population sufficed to feed a large tsetse population could be resolved by supposing that the game had regular habits which made them a dependable source of food; this raised the possibility that in such circumstances the tsetse could be starved by altering the habits of the game, without necessarily destroying it or even driving it away. Non-burning had the early effect of concentrating tsetse into certain restricted vegetation types, and the possibility of discouraging game from these limited areas was also to be considered. Finally "it is hoped to ascertain the effect of the successive removal of the game strata. As now roughly intended, first the large animals of relatively stationary habits would be removed, then those of the size of impala, reedbuck, and duiker, then the dik-diks. Possibly the pigs (warthog and bushpig) last, as it is doubtful if these form an important reservoir for the trypanosomes. One might find tsetses surviving in numbers but uninfected" (Swynnerton 1936, p. 284).

Work was started in the Shinyanga Blocks 9 and 10 in 1934 to investigate these points, as part of an ambitious programme including making (*a*) a detailed botanical map of each block, (*b*) a close game survey of all the mammals down to dik-dik size, the different herds, parties, pairs and solitary individuals being if possible differentiated, and the small species sampled by trapping, (*c*) a detailed density-distribution of the tsetses. The blocks were divided into squares with 2,000 yard sides marked by straight narrow hoed paths. The chief method was visual reconnaissances carried out by trained Africans who daily patrolled the paths and recorded what they saw. Early results are described by Harrison (1936) in a paper full of interesting information about the commoner mammals. After this it was decided to move the experiment to Kitalala, at the eastern end of Shinyanga District, near Lake Kitangiri. Here it was possible to work on a somewhat larger scale, with a larger variety of mammals, and free from the danger of interference from cattle which in one particularly severe dry season had invaded the Shinyanga block and disrupted the observations. The Kitalala work was hardly begun, however, when it had to be closed down on account of the war. After the war it was not reopened, but replaced by an experiment, requested by the East African Standing Committee for Tsetse and Trypanosomiasis Research, designed to determine whether the common savanna species, *G. morsitans, G. swynnertoni* and *G. pallidipes* Austen, would be eradicated by the destruction of the hoofed game animals. Blocks 13, 14, 15 and 16, which lay in western Shinyanga and Kahama Districts, were chosen for the site of this experiment. These blocks total about 600 square miles; they contained all three species of savanna tsetse, which were prevented from entering or leaving by wide stretches of treeless country on all sides. Game animals were prevented from entering or leaving by settlement on three sides, but a fence 50 miles long had to be erected on the north side to prevent the incursion of animals from an uninhabited game area.

All three species of tsetse disappeared from the experimental area, but the result was indecisive in the case of *G. pallidipes* which disappeared also from one of the control areas. The original intention of this experiment had been, harking back to Swynnerton's "successive removal of the game strata" to shoot only the larger animals and to spare the smaller antelopes and pigs. This proved impracticable, as it was impossible to prevent the shooters from killing these smaller species. It was considered that there must have been a great but unreported destruction of duiker, dik-dik, oribi, steinbuck, warthog and bushpig. The whole experiment was described by Potts and Jackson (1952) who summarized the work as follows:

"Game animals were shot in an isolated area of some 600 sq. miles over a period of about five years. The density of animals was originally in the neighbourhood of 10 to the sq. mile.

"This density is very low compared with densities recorded from national parks, and examination of the evidence available shows that the Tanganyikan bushland is understocked with game.

"As the result of the shooting in the present experiment, two species of tsetse fly, *G. morsitans* and *G. swynnertoni*, were exterminated, and a third, *G. pallidipes*, was either exterminated or very heavily reduced. Experimental cattle then remained healthy in the area for 11 months, after which they were removed.

"This result was achieved in spite of considerable invasion of the area by cattle, particularly intense at a late period when such an alternative source of food might have been expected to be particularly valuable to the tsetse.

"There was evidence that the fat, residual dry weight and size of the flies decreased, but there was no apparent effect on mean age or the proportion of females in the catches, nor apparently did the flies turn to avian blood.

"The cost was £50 per sq. mile; but this figure would be very much greater in normal practice, with areas not isolated from the rest of the fly belt.

"Game destruction is not recommended except in isolated areas of manageable size; discriminative clearing of the habitats, even at initially greater cost, is preferable as offering a more lasting solution."

This experiment did not show whether the tsetse could have supported themselves on small antelopes and pigs, because many of these were inadvertently destroyed. This point was recognized as important at the time, and it seems even more so now since the demonstration that Suidae in many areas contribute the greater part of the diet of *G. morsitans,* and in Shinyanga more than three-quarters of the diet of *G. swynnertoni* (Weitz and Jackson, 1955; Weitz and Glasgow, 1956; Glasgow *et al.,* 1957). This more recent work has been made possible by the development of sensitive and specific methods of identifying the origin of blood meals. These methods were elaborated by Mr. B. Weitz in the Lister Institute of Preventive Medicine, following a suggestion made by Buxton (1948; p. 37). The new technique makes possible much more precise enquiry into the relationships between game and tsetse. It is now possible to ask such questions as "why are dik-dik not fed on, although about as common as warthog?" (Harley, 1958) and "why are gorged flies habitually associated with some species of mammal but not with others?" (Isherwood, 1958.)

Returning now to Shinyanga in the early 1930s, another method of reclamation which was conspicuously successful in two places, Samuye and the Huruhuru plains, consisted in cutting off from permanent tsetse bush areas composed of a type of woodland unsuited for permanent occupation by tsetses. This method depends on the fact that there are in places extensive areas of woodland which are tsetse infested, but since they cannot supply all the requirements of the species of tsetse concerned all of the time, the infestation is dependent on constant reinfestation from a nearby permanent tsetse habitat. In such situations elimination of the tsetse can be achieved merely by destroying the connexion with the permanent tsetse bush, and if the terrain is favourable, as in Samuye and Huruhuru, this can be done at a cost which is small in relation to the benefits gained. Described like this, the method sounds almost too simple and obvious to be worth mentioning, but in fact it is only made possible by skilled survey work. Tsetses, as a gold miner might say, are where you find them, and it requires much experience to distinguish true tsetse habitat from some types of bush which are in fact occupied only by a constant immigration process.

In the account given above of the fire-exclusion experiments it was mentioned that they all started from a small road-side strip of bush which had been subjected to fire-exclusion in the hope of producing a barrier to *G. swynnertoni*. This search for tsetse barriers was continued for some years. In the early years it had been hoped that a sheer clearing 800 yards wide might be an effective barrier to tsetse; experience progressively increased this figure while the need for barriers became if anything more pressing. Thickets were the only alternative to barrier clearings which had been suggested. The thickets produced by fire-exclusion were fortified by planting various species of which *Euphorbia tirucalli* L. was the most effective. It was found that a belt of thicket 300 yards wide alongside a road greatly reduced the incidence of *G. swynnertoni* on the road, to about 15 per cent of what it would otherwise have been. Thicket of this width, however, failed to stop completely the passage of tsetse although it did impede them considerably. This thicket which had been made as a barrier to *G. swynnertoni* was found to favour *G. pallidipes*, and large populations of this species appeared, especially in the *Euphorbia tirucalli*. Good use of this was made in investigations of *G. pallidipes* (Vanderplank, 1941, 1944a and 1948) but eventually the *Euphorbia* was destroyed to oblige neighbouring cattle owners. After this experience artificial thickets as barriers to *G. swynnertoni* or *G. morsitans*, to mitigate infestation of roads or for any other purpose, could only be recommended in the certainty of the absence of *G. pallidipes*, and this condition is only seldom fulfilled.

Besides the very high density of *G. pallidipes* in the *Euphorbia* barrier, there was an enhanced population of this species in the whole of Block 4, the original fire-exclusion block. This was used in an experiment to control tsetse with DDT-treated oxen (Whiteside, 1949). The idea was to spray oxen with this insecticide so that tsetse feeding on them would be killed, and to introduce such oxen, under drug protection, into the bush in numbers exceeding the natural hosts. The practical difficulties were found to be so great that extermination was not achieved, and after the end of the experiment the population recovered in about three months. Though this rapid recovery was expected at the time, it is now of interest because elsewhere it has been found that tsetse populations recover only slowly, if at all, after reduction to a low level by insecticides (Hocking *et al.*, 1953). It may be that the Shinyanga *G. pallidipes* which recovered had been less drastically reduced than Hocking's *G. swynnertoni*. One reason for the failure of the experiment with D.D.T.-treated oxen was that the oxen were too few. In planning the experiment it was assumed that large animals (giraffe, greater kudu and impala) were of more importance to *G. pallidipes* than smaller game (bushpig, warthog and small buck). The number of oxen used exceeded the estimated numbers of large animals but not of small ones. It is now known, through the use of the serological tests mentioned above, that warthog is the most important host of *G. pallidipes* in Shinyanga, and therefore one of the basic assumptions of the experiment was unfulfilled. Whiteside noted that the only possibilities of improvement lay in splitting the herds and increasing the hours of grazing, both of which would have raised costs by necessitating extra herdsmen, or in increasing further the number of oxen. The number used, however, was near the carrying capacity of the bush.

One other reclamation experiment carried out in Shinyanga must be mentioned. This was by the method known as biological sterilization. A female tsetse is provided with a *receptaculum seminis*, in which sperm from a single mating can be stored and used to fertilize a series of eggs. One mating in fact may suffice for the whole life of a female tsetse, and the theory of biological sterilization rests in part on the assumption that one mating only is normal in nature. It was found that closely related species, such as *G. morsitans* and *G. swynnertoni*, would mate with each other, having apparently no means of distinguishing their own species from another (Jackson, 1945a). The hybrids resulting from such cross-matings are sterile (Vanderplank, 1944b). If, therefore, one could introduce an excess of foreign males into a given habitat a majority of the young native females would be mismated and so be sterilized, provided that they did not mate a second time. In practice, although large numbers of male tsetse can be caught, one cannot transport them in a healthy condition very far. One therefore has recourse to puparia, which in the case of *G. morsitans* at least can be collected fairly cheaply in certain areas and which travel satisfactorily through the post. The sexes of the puparia cannot be distinguished and approximately equal numbers of each sex emerge, so that there is a theoretical danger of replacing one species with another nearly-related one; but as there was some evidence that *G. morsitans* cannot reproduce itself indefinitely in the habitat of *G. swynnertoni* it was hoped that this would not occur. In the event the introduced species (*G. morsitans*) failed to eliminate the native one (*G. swynnertoni*). The experiment was carried out at Samuye, in an isolated block of about 6 sq. miles, with an initial population estimated at 900 *swynnertoni* males. Over the experimental period of 6 months it was thought that about 5,500 *swynnertoni* males were involved. During this period 50,000 male *morsitans* were allowed to emerge, giving a theoretical *morsitans*/*swynnertoni* ratio of 9/1. Catches, however, showed a ratio of only 4/1, to explain which discrepancy it was supposed that the *morsitans* males were less viable in the foreign environment. It was concluded that to achieve success it would be necessary to put in very much larger numbers of *morsitans*. The reasons for failure were not certainly established. While multiple matings, if they occurred, would greatly enhance the probability of a fertile mating, another factor was certainly contributory and may have been decisive. This is the fact that the two species, although similar, are distinct and react in slightly different ways to a given situation. Thus they tend to accumulate in slightly different places in the bush and so impose on themselves a spatial separation. It is worthy of note that *G. morsitans* did not become established at Samuye.

Another related experiment was carried out by Jackson (1945b, 1946, 1948 and 1950). In this, various species of tsetse were allowed to emerge from pupae placed in the habitat of other species. The pupae were exposed for only three days, so that the age of the "released" imagines was known with a possible error of plus or minus one day. The greatest interest centred in the release of *G. morsitans* in the habitat of the very similar and closely related *G. swynnertoni*. A second generation appeared in due course in spite of undoubted interference by the native *G. swynnertoni*; this interference must have hastened the disappearance of the alien species, which was, however, physiologically in a poorer condition and probably could not have survived indefinitely. *G. palpalis fuscipes* Newstead failed to produce a second generation in the habitat of *G. swynnertoni*; an explanation for this was recently provided by Bursell (1958) who found that pupae of *G. palpalis fuscipes* are killed by a degree of aridity which does not inconvenience *G. morsitans* or *G. swynnertoni*. These experiments provided a great deal of information, which could scarcely have been obtained in any other way, on such matters as relative activity at various ages, and the speed of natural dispersal through the bush. They also yielded a relation between age and wing-fray which, in spite of imperfections, does offer a means of estimating the age-composition of a sample of tsetses.

It will be noted that the experiment just described was of a somewhat more academic or fundamental character than the earlier ones. The objective was to obtain information about the habits and needs of tsetse, and not, as in the earlier experiments mentioned before, to test a method which was offering promise as a way of destroying tsetse. This change in objective has dominated the last decade of Shinyanga, with an increasing emphasis on laboratory work as laboratory facilities and laboratory trained personnel became available. It is not proposed to attempt to summarize here the mass of information which has been accumulated, and which is available, or in due course will be available, in the appropriate specialist journals. It should be recorded, however, that much of the work could only have been done in a laboratory in close contact with wild tsetse. It was not merely that there was close daily contact between field and laboratory workers, but in many cases the same individual carried out complementary field and laboratory investigations, thus tending to obliterate in a salutary manner the sterilizing distinction sometimes made between field and laboratory work. The observant reader will have noticed that the large scale field experiments in tsetse control came before the intensive investigation of tsetse biology—in the words of Jackson (1954) "the small Research horse after the large Reclamation cart". In recognizing that this was an error of procedure, let us avoid criticism of the pioneers of tsetse work. Swynnerton obtained with great difficulty scanty funds for his activities; it seems quite improbable that he could have obtained any funds at all for the more academic studies which should logically have preceded his experiments. Let us recognize too, however unsatisfied we may be with the present state of knowledge, that Swynnerton achieved his primary objective: the old-fashioned view that the correct response to any tsetse situation is to reach for a rifle is becoming progressively less popular in modern Africa.

It will be appropriate to close this account of tsetse work in Shinyanga with a mention of what has become known as the "long-term cycle". Continuous observations of tsetse numbers have been carried on for longer in Shinyanga than anywhere else. By averaging the catches from a number of fly-rounds over 12 months one can obtain a figure representative of that year. Such annual figures are not, of course, constant year after year, and it was found that they exhibited obvious trends, several years of increase being followed by several years of decrease, and so on. In a peak year the apparent density may be between ten and 20 times that of a trough year. Peaks and troughs have been separated by intervals of about five years. In 1948, a trough year, it was predicted that the numbers would rise to a peak in 1953 or 1954. This expected rise occurred; it faltered somewhat in 1952, an observation which was associated with exceptionally heavy rain in that year, but afterwards rose rapidly to a high value in 1954. The subsequent expected decline, however, has not occurred, the most recent figures available being little lower than those of 1954. The whole body of data still awaits a full critical review. Meanwhile it seems legitimate to maintain that the work "cycle", with its implication of regular and inevitable repetition, is not really applicable to this phenomenon. Further, it has sometimes been tacitly assumed that the area of the observations, Block 9, has been a completely stable environment, but this is not quite true. When the Block was first designated, more than 30 years ago, it was the north-eastern extremity of a large area of bush. Its southern and western boundaries had only cartographical existence. Parts of it at least had recently been cultivated, and of the subsequent maturation of the vegetation, and its possible effects on the tsetse, we have no precise knowledge. As time went on the block became more and more isolated, till now it stands as an island of 40 sq. miles surrounded by open cultivation steppe. That this process has affected the mammal population cannot be doubted, but again we have no precise knowledge of what changes have occurred, nor whether they have been of significance to the tsetse. Finally the block has not been entirely free of experimental reclamation. For a short time before the war it was put under fire-exclusion, as described above, and after that the southeast corner was subjected to discriminative clearing of the hardpans. Nevertheless, the observations do establish beyond any doubt that long-term fluctuations in tsetse numbers, involving a factor of ten or more, do occur. There is also evidence that similar fluctuations occur in other areas and with other species of tsetse. These fluctuations are apparently only by chance in step in different areas, and there is evidence that the interval between peak and trough may sometimes be quite different from five years. Although the theoretical background of these fluctuations is as obscure as ever, the fact of their existence is of enormous practical importance. It has been suggested (Jackson, 1954) that Swynnerton's initial success in Shinyanga may have been aided by a natural decrease in tsetse numbers coinciding with the application of his measures. Whether this was so can never be known, but it clearly might have happened, and it clearly might happen again.

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APPENDIX

DAR ES SALAAM,
7th August, 1921.

GAME CIRCULAR NO. 734/96.

To Supplement Secretariat Circular No. 74 *of* 1921.

TSETSE CONTROL

1. Grass fires now take place at a date at which they are useless. They can be so postponed and regulated as to serve most useful purposes in relation to the control of tsetse and of large vermin and the reclamation of waste country generally.

2. *Tsetses' Need of Low Shelter.*—Each species of tsete is dependent, in varying degree, on shade and especially on more or less low woody shade, packed or open, slight or great. This may require to be overshaded in addition (as, usually, in the case of *Glossina brevipalpis*) or not (as in the case of *G. morsitans*).

3. *Effect of Late Fires on Low Shelter.*—The action of late fires in relation to tsetse will be in part direct, through the greater destruction of tsetse pupae and breeding places which a really fierce fire can bring about and the probable hardship to the fly itself of a widespread and thorough removal of shade, concealment and food at a hot, dry time. Burning, as now, by small instalments, makes escape easy.

Largely the action will be indirect. The first fires take place when the grass is but half ready to burn and when (in most districts) there is not much recent leaf-litter on the ground. They attract little wind to swirl the flames into the tree-tops and thickets and they are small in extent. Late burning finds the grass and fallen leaves at their driest and most abundant and is so hot and so extensive as to draw in great wind. It achieves much actual destruction of low woody growth and a temporary destruction of much high shade as well. It should definitely place a check on the yet further extension of the vile thicket invasion that is now everywhere overspreading this country and Portuguese East Africa and rendering the effective control of tsetse in the future more and more improbable without a fabulous expenditure. Given enough grass, it will also very gradually destroy the thickets, shrubs, and small trees that already exist and shelter tsetse.

Destruction of pieces of bush of the types in question need not be regretted, seeing that they are more or less useless for timber, for water conservation or for any effect on the rainfall, and seeing also that the roots and stumps of many of the species are so tenacious of life that all that will be required in order to reclothe the country when our object has been anywhere achieved will be to stop late burning.

4. *Other Probable Good Effects of Late Burning.*—Investigating the baboon problem the writer was struck by the fact that outside of continuous high wooding and rocky or mountainous country the gardens troubled by baboons were those near which stood patches of the dense type of forest, useless for timber (and full also of two species of tsetse and their breeding places), that sometimes forms eventually on old cultivation. These are likely to be eaten out by fiercer fires. Leopards, again, are rarely found in large numbers in country devoid of thickets. The effect on ticks of late burning is well known and appreciated in South Africa and fierce and thorough burning should react usefully on noxious insects generally and on the snakes and small carnivora that are the chief enemies of insectivorous birds. A frequent thorough "burn" will be a grand general cleanser and disinfector of the country.

5. *Effects of Improper Burning.*—The writer has watched great areas of country revert to bush and thicket in Portuguese Gazaland during 20 years after the lapse of a previously existing prohibition of early burning that had accompanied a successful clearing of the country of fly. On his own land areas burned early for many years for early grazing went to dense thickets, while late-burnt ground beside them remained open. A dense forest that was protected advanced, at the deepest point, 90 paces in 15 years. Of our own territory it is stated that the German Veterinary Officers were convinced that the great and rapid spread of tsetse during the few years prior to the building of the railway was due to their Government's complete prohibition of burning for a number of years. Burning was afterwards allowed, but not regulated, and the mischief has more or less continued.

6. *The Best Method.*—The best results will by no means be obtained from mere late burning. The writer has had much personal experience of the special ferocity of "second-year" fires, has seen even large fire-resisting growth killed by them under varied conditions in dry years and has been also where areas of low dense forest full of tsetse have been burned off at one swoop as the result of the complete prohibition of burning for three years previously and of a consequent accumulation of inflammable material.

The best general method is to burn late and altogether miss burning in alternate years. This ensures an extra accumulation of fuel—and extraordinarily dry, effective fuel—and at the same time does not give the shoots and saplings of fire-resisting growth a serious start. It carries with it the disadvantage of giving cover to wild beasts for a longer uninterrupted period and will, when these give trouble, be criticized by the natives, but the resultant burnings will far more than make up for this temporary unpleasantness by their destruction of the permanent cover of such beast. This "alternate-year" method should be employed above all in any areas that carry tsetse in the three months of greatest leaf-fall.

7. *The Right Time to Burn.*—The burning, whether annual or every second year, should be done at the hottest and driest time of the year, so far as possible during the actual hot, dry winds and scorching weather and by day. The right time in some areas will be just before the small rains, in others, doubtless, just before the large. Protection of villages, exceptionally necessary in relation to such fires, should have been completed long before. Should the appropriate rains supervene before an area is burned it will usually be best to postpone for a year.

8. *Localities for the Measure.*—So far as tsetse are concerned it should theoretically be sufficient (for the effect on the vegetation only) to treat their dry season centres. In the areas examined here up to the present, however, small centres of one tsetse or another have been found more or less closely scattered throughout, and new ones are everywhere forming, so that it becomes necessary in practice to treat the entire belt, especially as a big expanse is needed to get a fire that will sweep off thickets. It will be well to treat all possible tsetse belts, as, apart from the

measure's prime object, conditions vary from belt to belt and the burning may in practice prove more useful under some conditions than under others and so provide us with useful lessons. Any area abuttting on tsetse that is itself under serious threat of invasion, and country at all infested through which run important roads or cattle routes could usefully be included.

Outside of tsetse-threatened country it may be desired to burn late for the reasons indicated in section 5. Here, however, may be mentioned the one good point about the thicket, a point that must weigh lightly against the presence of tsetse, but that may locally outweigh some other considerations: the thicket that is never entered by fire does accumulate humus better than ground that is burnt over, though it is true that 25 years of late burning in another part of East Africa left the soil exceedingly fertile.

In its extreme form the "grass-poor" country of much of the northern and central area lends itself less well to control by burning than do the remaining types of vegetation.

9. *Need for Thoroughness and for Careful Observation of Results.*—Being simple and inexpensive and owing to the extent of the fly-belts, the many and important species of tsetse and the great range of conditions—floral, faunal, elevational and meteorological—to which it will be applied, and the varied and useful suggestions that must therefore arise from its results if they are carefully watched and analysed, the present measure is capable, on this condition and with throughness of execution, of becoming the most important experimental measure yet initiated against tsetse.

Now many large-scale tsetse measures and tsetse events have been valueless as lessons or valueless altogether as the result of the lack of precise observation or through haphazard execution. The reduction of the fly in some of the fly-belts affected and not in others that occurred at about the time of the first rinderpest epidemic was never analysed, it is still unknown whether the extermination of the fly in the Hartley fly-belt was due to free shooting of game or the operations of a fuel contractor, the same kind of doubt applies to the great and successful native experiment under Umzila in the sixties in which late burning, game drives and judicious close settlement and clearing were all used, and apparently the white man's game drives have, so far, provided us with no lesson for the control of tsetse.

Particularly in view of this territory's special and crying need for a big-scale solution of the tsetse problem—by far the most important benefit that could be conferred on it—it will be regrettable if we should be found in this same position of indecision and wasted opportunity when, a little later, we take stock of our first results with a view to introducing effective modifications of or additions to our measure, and when also other countries will be looking to our conclusions for guidance. It is greatly hoped, therefore, (1) an especially, that it will be possible to carry out the measure very thoroughly wherever it is applied—for without this it will be useless—and (2) that it will be found practicable both to provide useful controls and in some way to keep in touch from the outset with the results of the fires.

10. *Controls.*—A convenient control in the form of a piece of land, defined and isolated, let us say, by road and river boundaries and carrying the same types of woodland and undergrowth as the late-burned areas round it, might be provided in each subdistrict affected. It need not be large and it should always be burned more or less early. The state of the woodland and thickets on this and on the adjoining late-burned areas will be compared from time to time. Such controls will give the general experiment a definite scientific value, which it will not otherwise possess.

Unfortunately they will record only the general relative effect on the vegetation of the different types of burning. For more definite information, and for information on other points, we must depend on observation.

11. *The Observations Required.*—Information as to the observed effect of the burning on the bush of each main type and on the game and other large animals is needed from the outset, and, if the tsetses' numbers and distribution seem affected also, it should, if at all possible, be discovered whether it is the fires' effect (1) on the bush, (2) on the animals and which animals, or (3) directly on the fly that is probably responsible for this. Any results to the small carnivora or to large vermin or to birds that may come to light should be recorded also, as should the general dates of the burnings, early and late, each year in various localities.

A difficulty in obtaining a useful record will result from the unreliability of native information and from frequent changes of

Political Officers, but it is hoped that it may be found possible to devise some system nevertheless. It is likely that the native's interest can be enlisted and that he will gradually, as happened in Gazaland under the Zulu domination, come to regard late burning as the only correct method.

12. *Protection of the Game.*—One of the many hopes from such an experiment is that it may indicate a surer, more feasible and less objectionable means than game extermination for fighting the fly on a great scale. It is important therefore that it should not itself be used as an exterminative measure or that the lighting of ring-fires should be allowed. Even the quite wide devastation that is probably necessary for the production of a direct effect on the tsetse on the wing will produce considerable movements of game and the results of these movements may be worth watching. Modifications of distribution certainly, and probably of habits, will also occur.

13. *Patience May be Necessary.*—Late burning, while employed alone (that is, unaided by previous ring-barking, judicious clearing, etc.), is likely to produce its modification of the woodland, if surely, very gradually. Our only woodland type that is not highly resistant to fire is the valuable "rain" or "primary" forest, included in Forest Reserves, that we are excluding from our operations. In addition, however, to the late fire's own use as a cleanser of the country and a slow clearer of bush the actual working of our present experiment is likely to suggest various local measures for its reinforcement, some of which might be feasible at once while others may find their turn when the present state of financial stringency has passed.

14. Many fires will have taken place already this season. It is hoped, however, that it will be possible to hold up further burning, at any rate in and beside definite tsetse areas, till the end of the present dry season. This will gain a year and give experience and result in a more useful organization of the measure next year.

All suggestions will be welcomed, and all observations, and it is hoped that white men generally will be sufficiently interested in this experimental attempt to conrol tsetse and other pests to refrain from burning the grass, even for shooting, before the word has been given, and will help all they can in the matter of the observations.

C. F. M. SWYNNERTON,
Game Warden.

PRACTICAL ASPECTS OF FIELD EXPERIMENTATION IN AFRICA

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This is a brief survey of some of the points which most need attention in field experimental work under African conditions, where many experiments are carried out by isolated officers who have little chance of discussion with technical colleagues. Many of the points appear quite obvious when listed, but a very great deal of time, enthusiasm and resources have been expended fruitlessly in African territories because such conditions have been overlooked or ignored.

Success in field experimentation depends upon:—

Asking the right questions.

Selecting a suitable design.

Suiting the field layout to the circumstances.

Supervising field work and devising foolproof routines.

Selecting appropriate numbers and sizes of samples.

Avoiding the uncritical application of routine methods of analysis.

Asking the Right Questions

Experiments can give useful information only if the ideas which you are testing, or the questions you are asking, are selected with enough skill and intelligence. First of all, do you know enough about the problem to begin experimenting? This implies an adequate knowledge of the subject and the collection of such valid evidence as already exists about the problem. These provisions alone would have prevented the laying down of many unnecessary experiments. Working through reports, papers and files in order to assemble the evidence may be very dull, but it takes less time and money than the growing of crops. Departmental archives are often inadequate, and records of past experiments may be hard to find, but on many agronomic problems the volume of experimental evidence is already very large. Any new experiment will add usefully to that store of knowledge only if it is designed in the light of recent progress, and then, of course, only if the records are properly written up, fully reported and detailed data filed in station archives or central libraries.

An exploratory approach is needed for practical investigations, whether they stem from fundamental work or have begun on a purely practical basis. In either case the questions posed in the earlier field trials should aim to locate the threshold of response to a treatment, the range of dressings, dosages, or concentrations within which response occurs, and indicate what other major factors may promote or limit the response or interact with the treatment.

At these early stages there may be some study of differences between places; but this is a complex question, and a thorough study of variations in the effect of treatment between different soils and climatic zones usually forms the concluding stage of a practical investigation. Although individual experiments may be quite well designed for the questions asked, many years of work on practical agronomic problems sometimes lead to inconclusive results. Inadequate study, in the earlier stages of the work, of interactions with secondary factors, or the choice of an inadequate number of sites in the later stages, are potent causes of such failures.

For experiments on fertilizers, where extensive field trials are designed to investigate interactions as well as main effects, it is quite common to neglect to see whether dates or methods of application affect the N-P-K results, or whether responses vary appreciably between different varieties. Variety trials continued over many years have been found to have given misleading results because inappropriate sowing dates or spacings have been used.

The importance of the sowing date in the tropics deserves special mention. Tropical climates are characterized by wet and dry seasons, the changes from one to another often being extremely abrupt; in consequence such factors as soil moisture and temperature, air humidity and available soil nitrogen may pass from one extreme to another within a few days. The correct timing of operations under these conditions becomes extremely critical. It is essential for the experimenter to have his preparations well advanced, for delay of a week or two in sowing may severely reduce yields. Yet all too often the experimental plots are sown with elaborate accuracy well after the carefree local cultivators have been guided by tradition to sow their own crops.

Unfortunately, under African conditions, the long distances, poor communications and difficulties of administering resident staff in remote stations all restrict the choice of experiment sites. This raises the question of how far the result of an experiment at one place in one year is, for practical purposes representative of an appreciable and definable fraction of the total farmland in all years. Very frequently a series of trials is done, each one being taken to represent a different set of conditions (e.g. of different soil type) and the results presented as if the result at each site indicates what happens under those conditions. This ignores the fact that a series of trials where each is done under apparently almost exactly the same conditions, often shows widely different results from trial to trial.

It is desirable, therefore, that the sites used should provide elements of replication within any groupings that may be defined. It is difficult to conduct experiments on peasant farmers' holdings; and yet if it is intended to apply the results to peasant farming practice, trials on government experimental stations may give inapplicable results. Thus, in seeking to ask the right questions in his field trials, the experimenter must make determined attempts to include an adequate range of sites.

Selecting a Suitable Design

For the preliminary stages of a field study, where it is necessary to include all the relevant factors and to see which interact and which are independent, the multi-factorial designs are extremely useful. When the range of questions has been narrowed down nothing more elaborate than randomized blocks, or, where appropriate, Latin squares need be considered unless there are over 12 treatments, and indeed randomized blocks may be adequate for 20 or even 30 treatments. More elaborate designs have as a common feature the use of blocks smaller than complete replications in order to reduce the errors due to soil variability within the latter; but unless some peculiar circumstances suggest that there will be an unusual amount of variation within a replication, the reduction in the error of treatment means achieved by the use of incomplete blocks of any sort is not likely to be greater than could be achieved by having one or two extra replicates. On major experimental stations where insufficient land is available for all the experiments waiting to be done, and where a statistician is at hand to help with complex analyses there may be a good case for using an elaborate design to save space in the field; but otherwise randomized blocks should be preferred to complex designs.

Many tropical crops, such as tea, coffee, cocoa, cotton and sisal require in their study a number of concomitant measurements so that the data comprise not only yields but quality factors and plant measurements. On the tree crops, in particular, the number of records being made can soon build up to astronomical magnitude; and if data such as this is to proceed without punch-card machinery it is essential to reduce each set of records to summary form as soon as it is taken. The difficulty of doing anything short of full analysis with the data from some incomplete block designs, gives another very cogent argument against using such designs for work on these crops.

There are, in practice, only two types of experiment in which the number of treatments is greater than can reasonably be put into randomized blocks—variety trials, and multifactorials. Following the publication of a range of balanced incomplete block and lattice squares types of design between 1938 and 1948, plant breeders began to make extensive use of these designs for variety trials; but it is now becoming realized that for up to 20 or 30 varieties the merits of these designs seldom outweigh the disadvantages. This is particularly true under African conditions, and experimenters would be well advised not to use them unless a statistician has specifically confirmed the need. With multi-factorials the device known as confounding is commonly used to reduce block size. For exploratory experiments the 2^n design with higher order interactions confounded is a powerful tool. In manurial work, where response curves for three or even four elements may be needed, the standard 3^n design is very convenient. Other confounded designs, in particular those for mixed series such as $3 \times 3 \times 2$, etc., may be used with advantage in fundamental research; but it is advisable to use them only after consultation with a statistician.

The query is often raised as to whether one replicate of a 3^3 design is sufficient at one site. If it forms part of a series, with at least two sites in each area for which it is required to quote a separate result, than one replicate per site will usually be enough. If only one site is available in each area, then it is best to have two replicates per site. More are rarely justified. It is pointless to know with great precision what happens on one acre of land when no other acre in the territory would give exactly the same result.

A device that can be used for factorial experiments, and that is in fact used by field experimenters far too often to add an extra treatment previously overlooked, is the split plot design. For a given number of plots this gains precision on some comparisons and loses precision on others. There are occasions when very little precision is required on one main effect (e.g. when one factor is of no interest in itself, but only in so far as it modifies the effect of the primary treatments) and then the use of split plots is clearly indicated. There are also occasions when some treatments can, by their nature, be applied effectively only to large plots while other treatments can be applied to smaller ones, and then a split design may increase efficiency by reducing the size of a replication. Unless these conditions apply, however, the only gain from the use of split plots may be a slight simplification of field working; and the sacrifice of precision on some main effects and the extra complexity of analysis (and of presentation of results) is too high a price to pay for this.

In some cases, particularly when there are five to eight treatments the Latin square design presents itself as an alternative to randomized blocks. The two-way block grouping of the Latin or Youden square can be invaluable in general biological work where there is sometimes more than one fundamental way of grouping units (e.g. animals can be grouped by litters, pens, birth weights, etc.) but in field experimentation it seldom gives any great gain. When for some other reason it is necessary to use more or less square plots, and hence the optimum randomized block arrangement of long narrow plots within compact blocks is precluded, there is something to be said for the Latin square; but, of course, the necessity to make the number of replicates equal to the number of treatments, is an irksome restriction. Youden squares have a certain attraction in so far as they give the advantages of the Latin square without this restriction; but what has been said previously about incomplete blocks designs again applies.

Perennial crop and other long-term (e.g. rotation) experiments pose special problems of design but the loss of time and money consequent on bad design is far more severe than on annual experiments and, therefore, statistical advice should also be sought before embarking on them. It is hoped that in the future there will always be a biometrical statistician either on the territorial or on the High Commission research staffs, but failing this the Rothamsted Department of Statistics can be consulted.

Field Layout

Within fairly wide ranges plot size is not usually very critical, the inherently higher variability of small plots being compensated by the lesser soil variation within small blocks; and on many arable crops any size between 1/100 and 1/30 acre is usually found to be satisfactory. As a general rule the lower end of this range is better for precision planted crops (i.e. planted at fixed intervals in rows of fixed width) where plot boundaries can be drawn exactly in relation to the plants while the larger plot sizes are better for irregularly sown crops. Tree crops present particular problems, and for these reference should be made to a publication by S. C. Pearce (Tech. Comm. No. 23, Commonw. Bur. Hort., E. Malling), 1953.

The optimum plot shape for reducing the error due to soil variability is long and narrow —the narrower the better—with the plots placed side by side. This, of course, points to the use of single row plots, which are also advantageous because they make for ease of controlling field operations. Long narrow plots, however, are all edge and no inside, and thus maximize any edge effects; which may be undesirable if no guard rows are used, and may be indirectly undesirable when they are used because an undue proportion of the total area is then occupied by guard row. In arable crops single row plots may tend to have higher errors than plots with two or three rows because some sources of variability tend to affect length of row rather than random plants, e.g. diseases which spread by plant contact, guinea fowl eating planted seed, rodents attacking standing crops. In bush or small-tree crops where large numbers of pickers have to be controlled in the field, single-row plots prove much more convenient, and are worth-while even where guard rows are needed.

In seeking a compromise between these conflicting lines of thought the experimenter should study and be guided by the actual errors of previous experiments.

Any effective field design will reduce variation due to difference in "blocks" of ground if these blocks or groups can be made to coincide with the major trends of variability. Therefore, as soon as the siting of a new experiment is proposed, the research worker must get out into the field and take some uniformity measurements in order to locate these trends. A complete season is not often justified: a few weighings of beasts, samplings for soil depth, three or four main pickings of coffee or tea, or a day spent measuring leaf length in sisal, may show up important trends in the variability of the experimental material. Even a detailed row-by-row count or eye-score may show up trends in a previous crop which are not at all obvious when looking at the field as a whole. With a long-term large-scale experiment, especially when these involve perennial crops, such preliminary work should be accepted as a standard procedure and evidence for it should be required, before permission is given to lay out the main experiments. Such uniformity data may determine the selection of a design, since if all the fertility trends or variations in the material are parallel then a Latin square wastes useful degrees of freedom which would be better devoted to the estimate of error. Should such preliminary trials or inspections give results of unexpected uniformity, do not be deceived as to the need for adequate replication and controls. A field in East Africa may give very uniform yields for three years of near average rainfall. A severe drought may then cause local crop failure on patches of shallow soil not previously suspected.

Organization of Field Work

With the simpler field experimentation in small plots the whole plot yield is normally weighed. This is not difficult in theory. In practice the obvious simple precautions require careful training and endless vigilance to secure their enforcement in the field. The preparation of numbered bags, and of numbered labels of wood or metal which travel within the sample bag to scale and on to the sieve or other means of preparation, are all of extra importance in African conditions, where most of the field labour may be illiterate.

In Britain and the U.S.A. agronomic experimentation is commonly tackled by teams of workers in which the proportion of graduates to junior technicians to labourers is about 1:1:1. In Africa corresponding teams often have ratios of the order 1:10:100, and the efficiency of such a team will clearly depend greatly not merely on how well the one graduate does his own work but also on his ability to train and deploy his junior staff to maximum effect.

Throughout tropical Africa many experimenters fall into one of three errors in this connexion. The first is to assume that the junior staff are quite competent to cope with the field work, and leave them to it with only brief instructions while concentrating personally on more "scientific" tasks. The magnitude of the errors that appear when the field results are subsequently analysed can then be staggering; moreover, this fault in organization can be self-perpetuating if the experimenter then wastes his time in trying to extract some sense out of these error-riddled results instead of making sure that the next season's results are better. The second error is a direct reaction against the first, the experimenter becoming so obsessed with the thought of what can go wrong in the field when he is not present, that he attempts personally to supervise all operations. There being limits to what one man can do, the total number of experimental plots has to be drastically reduced and the junior staff are under-employed. The third error, the collection of far more data than can ever be processed or thought about arises where organizing ability outruns experience in research.

More positive advice than the mere avoidance of these errors is to stress the importance of reducing field work as far as possible to foolproof routines. Instructions for these routines must include notes on how to cope with every foreseeable contingency, and must be devised so that there is double checking at all points where serious errors might come in (e.g. weighings); this means that much thought must go into them. It may often take longer to write instructions for a field operation than it would take to supervise it in the field, but since one set of instructions can be used for an indefinite number of trials the long-term advantage of working out such routines is obvious.

With well planned routines, teams of junior staff well trained in these routines, careful logistical planning and occasional surprise checks in the field, one graduate worker can control a very extensive experimental programme with acceptably low errors. Such an organization, however, must be built up gradually. A season's work on a few trials, perfecting routines and checking on the abilities of the junior staff to carry them out, should precede extensive trials. Careful study of the ability of each of the junior workers and adoption of the routines to suit these is in fact an essential part of success. Experience in both East and West Africa has shown that the employment of specially trained travelling teams to plant, to sample and harvest outstation series of trials does result in lower errors than if the work is left to less-experienced staff on the spot.

Sampling

Usually plots (apart from guard rows) should be no larger than the area whose yield is to be measured, but sometimes a treatment can, by its nature, only be applied to plots very much larger than can conveniently be harvested. This is frequently the case in pasture research, and occurs also in cultivation, in irrigation and occasionally in entomological treatments.

Apart from grazing experiments the sampling required is usually for observations other than yield in the standing crop and for determination of the useful fraction of produce harvested (e.g. dry, threshed grain; clean coffee, etc.). In either case a sound scheme of procedure cannot be devised without a knowledge of the pattern of variation. Suppose a number of rust lesions per leaf of coffee is to be estimated from a sample of leaves. One needs to know how the number of lesions varies between leaves on a branch, between branches, between upper and lower parts of the tree, between trees in a plot and between plots. Furthermore, if a procedure is to be used in several related experiments, it should not be based entirely on an investigation within one experiment; because the pattern of variation may itself vary with place, time, degree of rust incidence, and so on. Similarly, for crops where the yields harvested have to be substantially transformed to give yield of useful produce (pulping and fermenting of coffee, decorticating of sisal) it is worth making a study of treatments that are going to be applied in many experiments to see to what extent they vary not merely in yields harvested, but also in threshing, drying, fermenting, etc., fractions, and to determine the most efficient methods of sampling experimental harvests to get this data.

For both these forms of sampling, if the experimenter is in doubts about his sampling procedure he should consult a statistician, noting that the latter can do nothing without some knowledge of the pattern of variation. In applying procedures in the field, bias must always be guarded against. Strictly random working is usually tedious, and with unskilled field workers can easily degenerate into subjective selection of a most undesirable type. Procedures of the type "Take the 3rd, 6th and 9th plants in the 4th and 8th rows of each plot" are easy to operate and leave no room for bias to creep in. Strictly speaking, special methods are necessary to estimate the errors of systematic samples, but for most practical purposes it is adequate to regard them as random. They do, in fact, tend to give a more accurate estimate of the mean than random samples of the same size.

For bulky material of uniform size and condition quartering is useful, but this method can cause serious bias if the material has a wide range of particle sizes, such as those of soil crumbs before sieving. Automatic sampling devices such as divided chutes need a lot of preliminary testing, but may be worth while where large quantities of material are handled. A moisture meter is quite invaluable for testing grain and other samples. Its use makes it extremely easy to express all cereal yields in terms of a standard moisture content, say 12 per cent.

Turning now to grass plot sampling, this is a notoriously difficult subject, but the difficulties are often blithely ignored by the newly-fledged experimenter, who assumes that the yield must be the mean of such arbitrary size and number of sub-samples as he finds it convenient to harvest. Here some work at Muguga shows the dangers to be alarming. French, Robinson and Ledger (E.A.A.F.R.O. Ann. Rep. 1955 and 1956, and stencilled progress reports) tackled the problem of the size and number of sub-samples needed for assessing the weight of herbage in apparently even pastures.

Two test unit sizes were examined by harvesting ten samples of 1 sq. yd. and ten of 15 sq. yd., and then cutting the remainder of the grass in the three-quarter acre paddock, oven drying and weighing. This was repeated for three important pasture species with the results shown in Table I

TABLE I

Pasture Grasses	Herbage Estimated from Samples, as Percentage of Measured Total Yield	
	Unit Size	
	1 sq. yd.	15 sq. yd.
	Per cent	*Per cent*
Rhodes (*Chloris gayana*) . .	126	109
Star (*Cynodon dactylon*) . .	186	127
Kikuyu (*Pennisetum clandestinum*)	160	119

This was not good enough, so complete fields of each grass were pegged out into 432 small strips each 1 yd. × 6 yd. Using small motor-mowers and chaff-cutters and a very large steam-oven, the herbage on every sub-plot was harvested, oven-dried and weighed. It was then possible, by combining into successively larger units, to test for variability. The aim was to get a plot size which for ten replications would give a standard error per plot of 10 per cent or less of the mean yield (C. of V. 10 per cent). The complete experiment was repeated for successive cuts of the grass during the season, a total of 7,700 plots being harvested in one year. There was very marked seasonal variation. In Rhodes grass the minimum plot size for ten replications varied from 15 sq. yd. to 600 sq. yd., while in Kikuyu grass the range was 40 to 550 sq. yd. In each case the heaviest harvests were found to be the least variable, i.e. the luxurious wet season growth was more uniform than that of the dry season.

Analysis, Interpretation and Presentation of Results

During the last 30 years the application of the analysis of variance to the results of the field experiments has become ubiquitous; but unfortunately many—perhaps, even, the majority—of those using this technique to do so quite uncritically, applying it as an automatic routine in the light of which truth is revealed.

This is entirely wrong. To start with the use of the pooled error mean square as the basis for F- and t-tests of significance is dependent on assumptions of homogeneity and normality of error and of additivity effects which are never more than approximately fulfilled by the data; and not infrequently there are gross departures from these assumptions. The analysis of variance should not be used by those incapable of recognizing when it is valid to do so and when it is not.

In the majority of experiments the assumptions are fulfilled well enough for the pooled standard error of a plot to be a useful statistic; but the interpretation of results in the light of this error is never simply automatic. The experimenter who does no formal analysis, but who thinks carefully about the meaning of his results will be much more successful in the long run than one who applies formal routines uncritically. Always look at the raw data together with the field plan, i.e. study first the actual measurements as taken in the field. The junior computers should be reliable, and all computations must be checked independently, either by two of them, or by the experimenter if he has only one assistant, or twice by himself—but it is unwise to plunge into machine calculations on tabulated data without searching for trends and anomalies in the field results as collected.

Discretion is particularly necessary in the interpretation of significance levels: it must be remembered that the 5 per cent and 1 per cent probability points were quite arbitrarily suggested by Fisher and have no special properties. Effects which would, if true, have high importance, are worth following up even if significant at only the 20 per cent level in current work. If a large and important agronomic effect fails to reach significance, because errors are high, be careful to report that your experiment was unable to establish the effect, and avoid the implication that you have shown the effect not to exist. Even at the 20 per cent level there are four chances out of five that the effect is real, although not satisfactorily demonstrated. The interpretation of main effects and interactions varies not merely with their magnitude and their significance but also with the nature of the interacting factors. For this reason no simple rules can be laid down; and interpretation must remain a matter for discretion. As a general guide it might be said that when interactions are big, main effects often have little meaning; and this is also true of many treatment × place interactions. It is misleading to conclude that application of nitrogen is on average highly profitable if on an appreciable number of farms there is a less than economic response.

Where a simple design is used at several sites analyses of individual trials are usually fairly straightforward, but tend to be of little use in themselves. Their principal value lies in the use of plot standard errors to show which experiments have had unduly high errors—pointing to the need to use more regular sites, to tighten up field routines, or to control other sources of error—and also to indicate how many replicates per site are needed. Combined analyses of all trials are required; but unfortunately these are by no means straightforward. Textbook descriptions of the analysis of series of trials do not go deeply enough into the subject to be of much help with the more complex problems that arise in practice, so that consultation with a statistician is always advisable.

Fundamental work on the other hand is usually less concerned with series of trials and more with general biological data other than yields. It is necessary here to be on the lookout for unexpected distributions, and normality should not be assumed without careful inspection and, if necessary, statistical tests. The experimenter should be familiar with the logarithmetic and angular transformations, and know when it is appropriate to use them. The use of percentages, particularly if there are many very high or very low values, may necessitate angular transformations.

A refinement of the simple analysis of variance that is perhaps not widely enough known is the subdivision of the treatment sum of squares for particular degrees of freedom. When one factor has been present at several levels it is possible to underestimate seriously the significance of some real effects by F-testing only the pooled variance for all degrees of freedom of the factor in its main effect and in its interactions. The technique needs to be used with discretion, however, as it is possible for an element of subjectivity to enter.

In presenting the reports, apply common sense to the units and the decimal places employed. Root crops are better expressed in tons per acre, and the first decimal place is usually enough, e.g. a cassava yield is better given as 10.2 tons per acre than as 22,848 lb. per acre.

Finally, both the full data and the field notes should be put on record. There is never space to publish them, but they should be available for scrutiny, for re-analysis (e.g. by alternative transformations) and for study in the light of new knowledge by other workers who may follow.

THE FISHERIES OF LAKE VICTORIA, 1954–1959

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In any new fishery, after many years of exploitation, the fish catches become dependent upon the numbers of recruits becoming available for capture each year. To catch all these fish would require an infinite fishing effort (i.e. nets set per night), but a level can be reached where increased fishing effort will not increase the total catch but will tend to distribute the same number of fish over a greater number of fishing units causing a decline in the catch per net and hence the profits of individual fishermen. This occurred to the 5-in. gill net fishery for *Tilapia esculenta* in certain areas of Lake Victoria in the immediate post-war years.

During the early part of the century the gill net fishery of Lake Victoria was based primary on *T. esculenta,* but by 1927 there were indications that the abundance of this species was declining, particularly in the Kavirondo Gulf. In 1927-28 Graham surveyed the available fishery resources and, as a result of his study, recommended that the use of nets of 3-in to 5-in. (stretched) mesh size should be prohibited. This was put into effect, but until the period of the second world war there was a steady increase in fishing activity which was renewed when nets again became available in post-war years. During the ten years 1945-55 the level was apparently reached where further increase in fishing effort caused a decline in the catch per net and, consequently in individual profits. Enterprising fishermen then found that the use of gill nets of slightly smaller mesh, catching fish over a hitherto unexploited length range, gave relatively higher catches. Thus there was a very great incentive to use increasing numbers of illegal 4-in. to 5-in. mesh nets.

In 1956 the regulation recommended by Graham became exceedingly difficult to enforce and was removed in Uganda and Tanganyika. In 1957 Beverton of the Fisheries Laboratory, Lowestoft, visited East Africa in order to assess the status of the fishery. In his final report (1959) he made certain predictions for the future fishery prospects with the continued use of 4-in. to 5-in. nets; these were that there would be an increase in both the immediate and long-term catch of *T. variabilis* and possibly *Mormyrus;* an increase in the immediate, but a decrease in the long-term catches of *T. esculenta, Clarias* and *Protopterus,* and a decrease in both the immediate and long-term catches of lightly fished stocks of *T. esculenta,* and all stocks of *Bagrus* and *Barbus.* Beverton also added that he did not think that the increased catches of *T. variabilis* and *Mormyrus* would offset the loss of other species.

In the three years that have elapsed since the initial introduction of the smaller meshed gill nets significant changes have occurred in the number and weight of fish caught. The purpose of this paper is to outline these changes and to discuss their implications in relation to the predictions made in 1959 by Beverton and the earlier forecast by E.A.F.R.O. in 1955.

DATA

Records of the fish brought to the major fish landings around Lake Victoria have since the last war been maintained by the Lake Victoria Fishery Service; some have been analysed, *see* Lowe (McConnell), 1956, and Garrod, 1957. Trends in fishing before and after the war until 1956/7 have been discussed by Beverton (1959).

In this paper records from the major landings have been analysed according to the total fishing effort, total yield by numbers and the catch per net for the most important species namely: *T. esculenta, T. variabilis, Bagrus docmac, Barbus altienalis radcliffii, Mormyrus kannume, Clarias mossambicus* and *Protopterus aethiopicus.* Where possible the weight yielded has also been recorded; the weight data given are estimates obtained from the average weight of individuals of each species multiplied by the numbers landed.

An analysis of these records requires the compilation of a considerable quantity of tabulated data which cannot all be presented here, but since total yields are most important from a commercial point of view, data for all species have been aggregated. These data are given in the tables as monthly averages taken over six-monthly periods, January-June and July-December.

TABLE I.—THE TOTAL FISHING EFFORT (NET NIGHTS), TOTAL YIELD IN NUMBERS AND WEIGHT (TONS) AND THE CATCH PER NET (NUMBERS) AT MONTHLY AVERAGES OVER SIX MONTHS PERIODS AT FOUR STATIONS IN UGANDA

	MASESE				NAKIFALUBI				BUKAKATA				KATEBO			
	Fishing Effort	Yield No.	Yield Wt.	C.P.N.	Fishing Effort	Yield No.	Yield Wt.	C.P.N.	Fishing Effort	Yield No.	Yield Wt.	C.P.N.	Fishing Effort	Yield No.	Yield Wt.	C.P.N.
1954—																
1–6 . .	18,600	35,400	24·5	1·9	4,700	11,200	13·6	2·4	9,000	22,000	15·9	2·5	3,600	4,700	4·1	1·3
7–12 . .	16,100	24,800	19·5	1·5	9,600	25,000	25·4	2·6	15,000	26,300	23·5	1·7	10,200	23,100	28·6	2·3
1955—																
1–6 . .	9,900	22,900	18·2	2·3	9,800	20,200	25·7	2·0	10,000	21,000	17·5	2·1	10,100	11,700	11·1	1·2
7–12 . .	13,600	36,400	26·9	2·7	6,500	14,100	14·1	2·2	13,000	31,800	32·2	2·4	12,800	19,200	16·5	1·5
1956—																
1–6 . .	13,300	30,500	23·1	2·3	4,300	11,800	—	2·7	13,500	28,000	—	2·1	15,500	16,300	—	1·1
7–12 . .	30,600	94,500	56·2	3·1	19,000	43,100	—	2·3	16,600	21,000	—	1·3	14,100	19,700	—	1·4
1957—																
1–6 . .	52,000	161,600	93·9	3·1	14,800	42,500	—	2·9	12,900	17,300	—	1·3	9,800	10,600	—	1·1
7–12 . .	39,200	158,100	90·8	4·0	16,700	33,900	—	2·0	16,600	35,600	—	2·1	19,600	38,000	—	1·9
1958—																
1–6 . .	34,600	141,500	71·7	4·1	8,200	22,700	16·1	2·8	19,700	95,500	43·6	1·8	16,500	28,200	17·6	1·7
7–12 . .	40,000	122,800	65·0	3·1	7,500	14,200	8·8	1·9	19,500	40,700	22·8	2·1	18,800	22,400	13·4	1·2
1959—																
1–6 . .	53,400	129,600	70·1	2·4	5,500	6,900	5·1	1·2	13,400	62,300	32·5	4·5	6,600	5,500	3·7	0·8
7–12 . .	36,300	86,400	49·4	2·4	6,600	12,400	—	1·9	9,100	13,000	10·9	1·4	3,700	3,200	2·0	0·9

Fisheries of Uganda

Records are available from Masese (Buvuma Island area), Nakifalubi (Kome Island area) and Katebo and Bukakata (Sesse Island area). The records of commercial fish catches at these landings reflect basically the same changes in recent years and are given in Table I. Until the middle of 1956 the fishing effort was maintained at a fairly constant level and gave an equally constant yield, but the initial introduction of gill nets of slightly less than 5-in. mesh in 1956/7, led to increased catches which, with the corresponding increase in profits, attracted more fishermen.

At Masese the fishing effort increased from an average of 13,000 net nights per month early in 1956, to an average of 52,000 per month in the corresponding period of 1957. This unusually large increase in fishing effort was partly due to the reopening of the sleeping sickness area, east of the Nile to the Kenya border, which contained relatively lightly exploited fish stocks. Table I shows that a similar increase occurred in other areas though it was slightly later at Katebo and Bukakata. The yield in numbers of fish increased accordingly, at Masese the number of fish landed per month increased by 288 per cent between 1954 and 1957. Increased yields of up to 200 per cent were recorded at the other landings but owing to the use of smaller mesh sizes the increased yield by weight was not as great; at Masese this was 180 per cent. Records are not available from the other stations.

Analysis of the data according to the proportion of each species in the catch showed that major increases occurred in the yield of *Tilapia* species. *T. esculenta* increased because hitherto unexploited length groups of fish became available, and *T. variabilis* catches increased because this species grows to sizes that are liable to capture in large numbers in 4½-in. nets but not 5-in. nets. These increases occurred at all landings, but there was no increase in the catch per net of non-cichlid fish (i.e. types other than *Tilapia*); the yield in numbers of these species increased in proportion to the fishing effort but at the same time the weight yielded per net was very much lower. This was because the weight of individuals of a given species that are caught in 4½-in. and 5-in. nets are very different. This is shown in Table II.

Since 1957 there has been a marked decline in fish catches from these areas. It can be seen from Table I that by 1959 at Masese the catch per net, which is a crude index of the fisherman's profits, had declined to the level of 1955 when it was thought necessary to remove the restrictions on mesh sizes. At the same time the fish caught are smaller and do not fetch the same price.

Although the total catch at Masese in 1959 was much higher than in 1954/5, the decline in profits has led to a decline in fishing effort which has now in turn caused a decline in the total yield. This circle can only be broken when fishing effort declines to a level where the fishery has time to recover from the damage that has been done and an economic catch per net can be established. The fact that in 1958 the total catch at Masese declined despite a 15 per cent increase in the fishing effort is a clear indication of the dangerous state of the fishery. In the second half of 1959 both the fishing effort and the total yield were still declining.

Similar trends are obvious in the records from Nakifalubi and Katebo, and also at Bukakata if the corresponding halves of the successive years are compared. The particularly interesting feature at this landing is that whilst in both the second half of 1955 and the second half of 1959 the average monthly fishing effort was 13,000 net nights, the numbers of fish caught averaged 32,000 and 62,000 respectively, yet during both periods the weight landed was approximately 32 tons. This clearly demonstrates the smaller size of fish caught by 4½-in. nets. At Nakifalubi, Bukakata and Katebo, the state of the fishery during the second half of 1959 was as bad as it has ever been.

Table II.—Average Weight (Lb.) per Fish Caught in 5-in. and 4½-in. Nets

	T. esculenta	*T. variabilis*	*Bagrus*	*Barbus*	*Mormyrus*	*Clarias*	*Protopterus*
4-in. Nets (1955)	1·37	1·11	3·26	3·43	2·11	4·24	5·73
5½-in. Nets (1959)	1·14	0·85	2·03	2·51	1·02	3·26	3·81
% Change	16·8	23·4	37·7	26·8	51·7	23·1	33·5

Analysis of the records according to individual species shows that the increased yield of 1955/6 was attributable to better catches of *Tilapia* species, and the present decline has been caused by a substantial reduction in catches of *T. esculenta* and a slight decline in catches of *T. variabilis*. Catches of *Bagrus* have also declined slightly. These trends are in accordance with those predicted by Beverton in 1957.

FISHERIES OF KENYA

In Kenya waters an attempt has been made to maintain the restriction on the use of gill nets of 3-in. to 5-in. mesh, but it is known that a considerable number of nets of less than 5-in. mesh are in use.

Records have been kept over the period 1954-59 at Naia, at the mouth of the Gulf, at Sori, on the open lake to the south of Naia, and at Kaloka, within the gulf. Records from 1954-58 are available for Port Southby, outside and to the north of the gulf, and for 1955-58 at Wicklum, which lies between Port Southby and Naia. The only consistent records from within the gulf are from Kaloka. 1958-59 records are available from Nanga where records were also kept in 1952. These will be referred to but are not tabulated in Table III.

The individual landings at Kenya waters are smaller than those recorded in Uganda but this bears no relation to the total fishing effort in either territory. In fact the canoe registrations in Kenya are slightly less than in Uganda but because the area fished is also much less it is very probable that the fishing intensity, i.e. nets per unit area, is very much higher than in Uganda. Of the Kenya landings Kaloka has been the largest until recently. This reflects the fact that the greatest intensity of fishing occurs within the Kavirondo Gulf.

The records from Kaloka for 1954, 1955, 1956 show clearly that the effort, yield and catch per net were fairly constant indicating a stable fishery. In 1957 the fishing effort increased partly as a result of a general expansion of the industry and also owing to the influx of a number of illegal nets of less than 5 in. The first halves of 1957 and 1958 showed an increased yield with increasing effort, but the increased catch per net was not long maintained. Since the second half of 1957 it has declined steadily, the total yield has dropped and as a result the fishing effort has decreased, until in the second half of 1959 it was only 10 per cent of the level at the beginning of 1958.

Owing to the lack of data it is not known how far this reflects the general state within the gulf. It may be that increased effort elsewhere has kept the overall yield constant despite the drop in catch per net. However, at Nanga also the effort and yield is less than in 1952; the catch per net, which indicates stock density, is less than half its former value. Assuming increased effort at the same time as at Kaloka (1957) then the same conclusions are inescapable that in the Kavirondo Gulf the total yield and catch per net are declining causing a decrease in fishing effort. Despite the use of a proportion of 4½-in. nets there has been no increase in the numbers of *T. variabilis* landed.

At Naia fishing effort increased in 1957/58 giving a corresponding increase in yield, but since then a slight decline has occurred. No single species predominates in the catches at this landing and the poorer catches of 1959 are due to fewer *Bagrus* and *Mormyrus* rather than a decline in *Tilapia* species.

At the Kenya landings outside the Kavirondo Gulf a general increase in fishery effort has occurred with increasing yield and a slightly declining catch per net. These landings are developing relatively lightly exploited areas and probably reflect the movement of fishermen away from the Kavirondo Gulf where profits have declined.

FISHERIES OF TANGANYIKA

Tanganyika Territory has the longest and least accessible shoreline and records of commercial landings are more difficult to maintain especially since much of the fishing effort is carried out by migrant fishermen. Data on the total fishing effort in any one area is not reliable although a crude index can be obtained from canoe registrations in different areas. Catch per net data, which are less affected by gaps in total records, are available from Nyang'humbi (Speke Gulf), Mwanza South, Nyamirembe (Emin Pasha Gulf) and Bukoba.

As in Kenya and Uganda the numbers of canoe registrations indicate that fishing activity has increased during the last three years. At the same time the numbers licensed at Nyang'humbi, Musanza District and at Mwanza decreased in 1958 whilst canoes licensed at Nyamirembe, Bukoba, and other outlying stations increased.

TABLE III.—THE TOTAL FISHING EFFORT (NET NIGHTS) TOTAL YIELD IN NUMBERS AND WEIGHT (TONS) AND THE CATCH PER NET (NUMBERS) AT MONTHLY AVERAGES OVER SIX MONTHS PERIODS AT FIVE STATIONS IN KENYA

	PORT SOUTHBY				WICKLUM				NAIA				SORI				KALOKA			
	Fishing Effort	Yield No.	Yield Wt.	C.P.N.	Fishing Effort	Yield No.	Yield Wt.	C.P.N.	Fishing Effort	Yield No.	Yield Wt.	C.P.N.	Fishing Effort	Yield No.	Yield Wt.	C.P.N.	Fishing Effort	Yield No.	Yield Wt.	C.P.N.
1954—																				
1–6	600	1,500	—	2·5	No records				1,900	4,200	—	2·3	400	2,000	—	4·9	9,100	16,900	—	1·8
7–12	900	3,000	—	3·2					1,500	3,400	—	2·3	400	1,700	—	3·8	7,900	11,100	—	1·4
1955—																				
1–6	900	3,800	3·1	4·2	4,200	12,100	10·1	3·0	2,900	5,700	5·0	2·0	600	2,200	2·1	4·0	9,400	14,100	9·2	1·5
7–12	1,500	4,400	3·8	2·9	4,000	9,800	8·9	2·5	2,500	4,400	3·7	1·7	1,100	4,400	5·9	4·5	9,100	10,700	7·0	1·2
1956—																				
1–6	2,500	7,200	—	2·9	4,400	8,600	—	2·0	1,500	4,000	—	2·7	800	3,200	—	4·0	5,700	9,000	—	1·6
7–12	2,500	7,400	—	3·0	6,400	14,300	—	2·2	3,300	6,600	—	2·0	600	3,200	—	4·9	7,600	10,800	—	1·4
1957—																				
1–6	5,100	13,900	—	2·7	11,300	47,900	—	4·2	4,900	14,300	—	2·9	1,000	4,100	—	4·3	11,800	25,900	—	2·2
7–12	4,900	10,300	—	2·1	9,200	17,800	—	1·9	4,500	8,800	—	1·9	1,600	4,900	—	3·1	11,600	12,600	—	1·1
1958—																				
1–6	6,100	10,100	8·0	1·6	9,800	19,300	13·7	1·9	4,200	10,300	9·3	2·5	1,900	5,100	4·7	2·6	19,600	22,600	15·4	1·1
7–12	6,300	13,000	11·3	2·0	8,200	19,100	15·7	2·3	5,600	8,100	7·9	1·4	2,400	6,600	7·5	2·7	17,300	12,500	9·0	·7
1959—																				
1–6	No records								5,400	7,200	5·6	1·3	4,700	6,800	6·9	1·4	7,300	5,800	4·2	·8
7–12									4,700	6,100	—	1·3	4,400	7,400	—	1·7	2,100	1,700	—	·8

Catch per net records at Nyang'humbi and Mwanza South, the most accessible fishing areas, have shown a decline whereas those of other landings have been maintained. With the indication of increased effort at these more distant landings presumably the total yield has also increased.

Small meshed nets are allowed in Tanganyika, but the preference of fishermen for 5-in. nets in some areas is a valuable indication of the state of fishery. On theoretical grounds it is known that for *T. esculenta,* the most suitable gear is the 5-in. gill net which gives a higher catch per net than any other gear on a lightly fished population. With heavy exploitation of the species the size range of the exploited stock may be changed such that a 4½-in. net gives a better return. This has been seen in Uganda. In Tanganyika the continued use of 5-in. nets and the statistics available, show that catches of 4½-in. nets are not better than those of 5-in. nets, and in any event catch smaller fish. The clear implication is that the Tanganyika waters are less heavily exploited than those of Kenya or Uganda.

DISCUSSION

The catch statistics of all three territories reflect the same trends, there has been a general increase in fishing activity during the past three years which has led to varying degrees of depletion of the inshore, more accessible, fishing grounds. This, in turn, has caused fishermen to move further afield.

This expansion is demonstrated in Uganda by the decline in fishing at Nakifalubi and Katebo and is known from personal observation in the Jinja area, although actual records from outlying landings are not available to demonstrate it. In Kenya the development of landings outside the Kavirondo Gulf and a decline in fishing effort within the gulf suggests the same thing and again in Tanganyika the canoe registration at Nyang'humbi and Mwanza South have decreased whilst those at Nyamiremebe and elsewhere have increased.

The important point for consideration is the degree of depletion which has occurred to induce the search for better fishing grounds even though they may be too far from markets for fresh fish to be landed.

There are three phases in the development of a fishery using a particular gear. Initially when a population is first exploited a few nets will yield a high catch per net, although the total yield will be low. As fishing increases the total yield will increase, but at a progressively slower rate, and the catch per net will decline. Ultimately fishing effort may reach the level where so many fish are removed that the population is unable to maitain itself and at this point the total yield and catch per net will decline.

In the Kavirondo Gulf, where there has been a less widespread change in the commercial fishing gear, the available evidence indicates a decline in both the total yield and the catch per net.

If the characteristics of the fishing gear are altered by a change in mesh size one overall effect is to upset the equilibrium that had obtained. A new equilibrium will not be established for a considerable period of time.

Data from the Uganda recording stations indicate that in 1955 the fishery was declining slightly as a result of increased fishing activity. The decrease in mesh size in 1956 gave increased catches which attracted more fishermen. This change in conjunction with the growth characteristics of the three most valuable species, *T. esculenta, T. variabilis* and *Bagrus,* indicated that the increase in fish catches would not be permanent. It can now be seen that the anticipated decline has occurred.

At Masese and Bukakata both the yield and the catch per net have declined; both criteria are at present approaching the pre-1956 level and are still declining. At Masese the decline has been offset by exploitation of the sleeping sickness area, all of which is now heavily fished. At Bukakata the catch in numbers is now heavily dependent upon *T. variabilis,* but the weight yield is no better than in the pre-1956 period.

At Nakifalubi and Katebo the industry has deteriorated somewhat further in that the increased fish catches were very temporary and the yield and catch per net declined to the level where fishing was no longer economic and the fishermen moved elsewhere.

It can thus be seen that, as with the Kavirondo Gulf fishery, the industry in the vicinity of the major landings of Uganda is now in the third phase of decline.

In Tankanyika's waters the overall level of exploitation is lower than in Kenya and Uganda and fishermen have moved to more profitable areas before the catch per net declined to the levels that have been noted in the other territories. It is not clear whether or not the total yield also declined.

At most of the landings where records have been maintained, the catch per net has declined to a level where individual profits are no better than in the pre-1956 period although there has been an intervening boom in some areas with the use of $4\frac{1}{2}$-in. nets. This gear gave a temporary increase in catches of *T. esculenta* and an increase in *T. variabilis* which is also expected to decline slightly. There was no increase in the catch per net of non-cichlid species and, in fact, *Bagrus* has declined slightly in some areas.

These trends are strikingly similar to those predicted by E.A.F.R.O. in 1955, and by Beverton in his final report, 1959.

The overall effect of the use of $4\frac{1}{2}$-in. nets in Uganda waters has been to encourage excessive fishing so that now the yield at some landings is as low as that obtained four years ago, and is still declining. Even without the change in mesh the data from fish landings in Kenya indicate clearly that fishing intensity has been too high on the most valuable inshore fisheries.

The development of new grounds both inshore and offshore means that despite the decline at long-established fishing centres the total yield from the lake may not have shown a serious change. However such geographical expansion is limited particularly since the open lake, except in the vicinity of islands and reefs, does not yield a return that makes it worthwhile for commercial fishermen to risk the hazards involved. In Kenya and Uganda there are very few new areas remaining to be exploited. It is also certain that the species caught further out are less valuable and also that, if fishing effort remains at the same level, trends that have been noted on inshore fisheries, will be repeated.

This would be less serious if the inshore fisheries were to recover in the meantime, but without some active management policy this will be impossible because there will always be fishing as soon as it is possible to make a marginal profit. Unless fishing effort is curtailed either by legislation or by the internal economics of the industry the stocks of fish in Lake Victoria may decline still further.

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THE BREEDING BEHAVIOUR OF MOLASSES GRASS IN KENYA

By A. V. Bogdan, Grassland Research Station, Department of Agriculture, Kitale, Kenya

(*Received for publication on 10th February, 1960*)

In 1954 the comparison and selection of varieties of Molasses grass (*Melinis minutiflora* Beauv.) suitable for leys was undertaken at the Grassland Research Station, Kitale. This type of work necessitates a certain knowledge of the breeding behaviour of the species concerned and as no information could be found in the literature a study of progeny lines was undertaken to find out whether Molasses grass is cross-pollinated or self-fertile. Four distinct varieties were chosen for this study. They differed in general habit, and in such characters as the nature of the hairs on the leaf-sheaths close to the nodes, the colour of the leaves, the hairiness of the spikelets, the length of the awns, and other features. The varieties were:—

1. K5180* from Nyasaland: spikelets hairy with very long awns.
2. K51149 from Chania River, Kenya: spikelets glabrous with rather short awns.
3. K51296 from Kapenguria Escarpment, Kenya: spikelets hairy and awnless.
4. K51321 from Rongai, Kenya: spikelets glabrous with long awns.

In 1954 these varieties were planted from splits in adjacent rows, 4 ft. apart. Seeds were collected from each row and these were sown in 1955 in boxes and the young plants transplanted to adjacent plots, 70 plants in each plot. Seeds from these plots were again collected and the same procedure was repeated in 1956 and in 1957. As some varieties begin flowering earlier than others, all seeds were collected on the same day, from panicles which had reached the same stage of ripening and it was assumed that they flowered at about the same time. In each of the three generations of progeny lines under study, all plants of the same variety remained quite uniform and true to type. There was, however, one exception in the second generation of the Chania River variety. This off-type plant was distinct from all the four original varieties, and it differed from the mother plants in having a less prostrate habit, darker leaves, a different type of hair at the nodes, shorter awns, and slightly darker panicles. It developed only a few seeds and appears to be a natural hybrid. The facts described above show that varieties of Molasses grass do not normally cross, even if grown close together, although occasional hybridization may occur, in this case once only in the 840 plants under study.

The fact that in Molasses grass pollen from another plant is not needed for seed formation was also demonstrated by bagging a few plants of the Chania River variety. Six panicles were enclosed in bags before flowering, and when ripe 400 spikelets of each panicle were examined. Of 2,400 spikelets 645 or 26.8 per cent contained caryopses. The number of caryopses developed in the six control-free flowering panicles was 1,024 or 42.7 per cent, again out of 2,400 spikelets. Bagging five panicles of another variety (K51144 from Cherangani, Kenya) resulted in 276 caryopses among the 2,000 spikelets (13.8 per cent) of the bagged heads, as against 640 caryopses (32.0 per cent) in the control heads. A lesser number of caryopses per 100 spikelets in the enclosed panicles may well be explained by the somewhat abnormal conditions for flowering and seed development inside the bags.

In the *Paniceae* tribe of the *Gramineae* apomixis is a frequent phenomenon [Brown, 1] and it seems likely that Molasses grass is not even a self-pollinated species but an apomict, which, however, may cross-pollinate very occasionally. A microscope study of the process of fertilization and seed formation is, however, needed before one can be quite sure of the apomictic nature of this species. For the purpose of strain building, the fact that Molasses grass is not a cross-pollinated species indicates that strains can be developed from single selected plants, and it also indicates that varieties can be grown for seed without the need for isolation, as far as cross-pollination is concerned.

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* The K figures denote the introduction numbers of the Kitale Grassland Research Station.

According to Stapf and Hubbard [2] *Melinis minutiflora* has glabrous spikelets and one might think that of the varieties under trial those with hairy spikelets do not belong to *M. minutiflora* but rather to *M. maitlandii* Stapf et C. E. Hubbard or *M. tenuinervis* Stapf. It appears, however, that the hairness of spikelets alone is not a reliable criterion for distinguishing the species of the *Melinis minutflora* complex and I think that all four varieties under study, as well as the majority of other varieties grown at the Grassland Research station, belong to the same macro-species which includes numerous micro-species or "varieties". A revision of the *M. minutiflora* complex and its affinities, including observations on progeny lines, is required before the taxonomy of this group can be clearly resolved.

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REVIEW

Bracken: A Review of the Literature, by K. W. Braid, Mimeographed Publication No. 3/1959 of the Commonwealth Bureau of Pastures and Field Crops, published by Commonwealth Agricultural Bureaux, Farnham Royal, Bucks, pp. 69, price 7s. 6d.

Bracken: the third publication in the current series issued by the Commonwealth Agricultural Bureaux, has a format similar to previous volumes. Mimeographed works have their limitations but at its price this one is excellent value. The available data is presented with admirable clarity and the author, associated with bracken and its problems for over 25 years, is to be congratulated on a terse but knowledgeable review. The bibliography of more than 400 specific references indicates the scope and magnitude of his task.

The bracken problem has been accentuated as modern developments in agriculture have opened up more and more marginal land. Increased efficiency and intensive land-usage have been accompanied by soaring costs and although bracken eradication is fundamentally an ecological problem, interim remedial measures are exhorbitantly expensive.

The publication is recommended to all readers, for it deals with an agricultural pest of startling vigour and the history of bracken indicates the ease with which an apparently harmless and not unattractive plant can colonize and engulf land, once habitats are disturbed by man. It would behove farmers at high moist altitudes in East Africa to watch the behaviour of bracken with some interest.

O. K.

EPERYTHROZOONOSIS IN SWINE

By D. W. Brocklesby, East African Veterinary Research Organization, Muguga, Kenya

(*Received for publication on 7th December, 1959*)

Recently we have observed eperythrozoa in blood smears from a pig in Kenya. The following review was undertaken therefore to draw attention to the possibility that pigs in East Africa showing symptoms of anaemia or jaundice may be suffering from eperythrozoonosis.

HISTORICAL

A disease of swine called "ictero-anaemia" or "anaplasmosis-like disease" was reported consistently from the Middle West of the U.S.A. between 1932 and 1940 (Kinsley, 1932; Doyle, 1932; Kinsley and Ray, 1934; Dicke, 1934; Quin, 1938; Kinsley, 1939, and Spencer, 1940). Robb (1943) discussed these early reports. The writers reported that examination of blood smears revealed protozoan or anaplasma-like bodies in the red blood cells. The bodies varied in morphology. Some were coccoid, some bacilliform, while others were ring-formed. The latter often had chromatin knots or masses on their circumference. Robb (1943) considered that the bodies were actually artifacts produced in the process of smearing, staining or drying and he concluded that the aetiology was unknown but that it was not caused by an anaplasma as was previously believed.

In 1950, Splitter and Williamson found that a species of eperythrozoon was associated with three separate outbreaks of an acute icteroanaemia in swine and obtained evidence indicating that the parasite was the causative organism. In a number of publications Splitter subsequently amplified the above conclusion and described two species of eperythrozoa of pigs (Splitter, 1950a, 1950b, 1950 c, 1951). *E. suis* is pathogenic and *E. parvum* is not. The original description of these two parasites (Splitter, 1950a) is given below.

> "*E. suis* is a large eperythrozoon containing somewhat more chromatin material than other species of this genus. A ring structure which averages about 0.8 μ in diameter is the principal form of this extracellular parasite. At the height of parasitic attacks very large ring and discoid forms are present. These vary in size from 1 μ to 2.5 μ Many of the large ring forms are of distorted shapes, and exhibit an irregular distribution of the chromatin at various points about the ring. Discoid forms appear as flat, solid chromatin masses. Coccus, rod, and various budding forms are also observed. The organisms are usually found upon the erythrocytes, and may be so numerous as to cover the red blood cells completely. Morphological changes occur within a few minutes in citrated or oxalated blood samples. Coccus and rod forms predominate in samples so treated."
>
> "*E. parvum* is observed primarily as small coccus forms and occasional ring structures. The rings are approximately 0.5 μ in diameter and the coccus forms are somewhat smaller. This parasite has displayed a tendency to accumulate in large numbers upon individual erythrocytes, even when very rare in the blood smear."

In another paper Splitter (1950b) gave a full and useful account of *E. suis* infection and stated that a serious or fatal ictero-anaemia resulted in all experimental pigs in which initial attacks of *E. suis* were allowed to proceed without treatment. Parasites were demonstrated in blood films from two to five days following inoculation of susceptible animals or splenectomy of known carriers. He considered that *E. suis* was a common blood parasite of swine and that the majority of older animals were exposed and infected when young and remained permanently immune, latent carriers. Clinical cases usually were diagnosed, therefore, only in young susceptible swine which were exposed to infection from carriers. He concluded that the disease of swine described in the literature as "ictero-anaemia" or "anaplasmosis-like disease" was the result of acute infection with *Eperythrozoon suis* and that if additional agents were found to produce similar symptoms and pathology, it would be necessary to differentiate them from acute eperythrozoonosis. In this paper Splitter published two very good photographs of the parasite.

Controversy broke out in 1951 when Foote, Brock and Gallaher published their conclusions that "ictero-anaemia, eperythrozoonosis, or anaplasmosis-like disease of swine" was caused by a filtrable virus, which would pass through a 12 lb. filter and possible finer filters. Moreover, eperythrozoa were not present in blood films made from all clinical or experimental cases of virus anaemia and, when observed, were either reactionary bodies or artifacts or were coincidental with the disease and were not pathognomonic of the disease.

Splitter replied in three papers (1951, 1952 and 1953a) with an exact study of the filterability of the two species. *E. suis* was passed through bacteria-tight filters in four of 29 individual serum filtrates. The parasite was completely removed from the same infectious sera by filters of finer porosity. *E. parvum*, the non-pathogenic species, passed through filters of fine porosity. Splitter was unable to recover "the virus of Farley", which Foote *et al.* maintained was the cause of the condition, from field and experimental cases of acute eperythrozoonosis and concluded that eperythrozoonosis was not identical to the condition described by Foote *et al.* as "virus anaemia". He considered that full acceptance of "virus anaemia of swine" as a disease entity must await its reproduction consistently and entirely in the absence of eperythrozoa.

Berrier and Gouze (1954) described 73 deaths in a group of 90 piglets and suggested that eperythrozoa, which were seen in blood smears of the affected piglets, were the cause of death and that they were transmitted *in utero* from carrier sows.

The role of *E. suis* as an occasional pathogen of pigs now appears to be established and accepted. Subsequent work has been largely confined to geographical records and further conjectures as to its virulence.

Jennings and Seamer (1956) recorded the occurrence of *E. parvum* in splenectomized pigs in Britain. Jansen (1952) found *E. parvum* in a splenectomized pig in South Africa and suggested that *Haematopinus suis* might be a vector. According to Henning (1956), both Neitz (1955) and Grosskopf (1955) saw *E. suis* in South Africa; Gillain (1942) found *E. suis* in the Belgian Congo. Biberstein, Barr, Larrow and Roberts (1956) found eperythrozoa in pigs in New York State.

Splitter (1953b) described an iron-reacting inclusion of pig red cells associated with an acute haemolytic anaemia attributed to eperythrozoonosis. The inclusions were similar to those seen in human patients affected with congenital familial anaemia and acquired haemolytic anaemias of unknown aetiology.

In 1958 Splitter described a complement-fixation test for the diagnosis of eperythrozoonosis in swine.

Adams, Lyles and Cockrell (1959) reported an outbreak in a herd of Landrace pigs, in Alabama, in which a prominent symptom was a weakness of the hind legs.

SYMPTOMS AND TREATMENT

The disease is characterized by symptoms of fever, depression and anorexia. Severe and rapid blood destruction quickly follows at which stage the parasites become reduced in numbers. The affected animal then exhibits a lowered temperature, pale and icteric mucosae, marked weakness, and constipated, bile-stained faeces at the onset of acute anaemia.

Splitter (1950d) has shown that a single intravenous dose of neoarsphenamine (15-45 mg./kg.) is an effective treatment.

CONCLUSION

Two species of eperythrozoa are commonly harboured by pigs. One of these, *E. parvum,* is non-pathogenic, and the other, *E. suis,* may be responsible for an "anaplasmosis-like disease" of swine. The possibility that pigs showing symptoms of anaemia or jaundice may be suffering from eperythrozoonosis should be borne in mind. Neoarsphenamine (Evarsan; N.A.B.; Neokharsivan; Neosalvarsan; Novarsenobillon; Novostab) is the drug of choice.

ACKNOWLEDGEMENTS

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REVIEW

THE MEASUREMENT OF GRASSLAND PRODUCTIVITY, edited by J. D. Ivins, published by Butterworth's Scientific Publications, London, 1959, pp. 207, price Sh. 35.

"The measurement of Grassland Productivity" was the subject discussed at the Sixth (1959) Easter School in Agricultural Science held at the University of Nottingham School of Agriculture and, since grass is grown to feed livestock, the techniques which bring livestock into the final assessment of grassland productivity received major consideration.

This book is a record of the proceedings of this symposium. It is arranged in five sections, only the three most important of which may be mentioned here. These are respectively concerned with the measurement of (i) herbage growth; (ii) the consumption of herbage by livestock, and (iii) animal production from grassland.

Contributors to each of these sections are well known authorities in their particular field and they do not hesitate to present the difficulties associated with the measurement of grassland productivity or to admit the lack of confidence in the methods which may be used to measure and to compare grassland productivity under different conditions and treatments.

The accurate assessment of grassland productivity by direct means or through livestock is a global problem and those of us who happen to be concerned with it under East African conditions should find that this book makes very stimulating and purposeful reading.

H. W. D.

OBSERVATIONS ON GRASSES AND LEGUMES UNDER GRAZING

By R. Strange, Grassland Research Station, Kitale, Kenya

(*Received for publication on 21st March, 1960*)

Field-scale trials are being established annually at Kitale to evaluate grasses and legumes under grazing, and this note concerns one which began in 1954 and was continued until 1958.

In this trial the following grasses and legumes were sown at right-angles to each other in a "grid" arrangement.

GRASSES	LEGUMES
Rhodes grass (*Chloris* gayana) var. Nzoia, Endebess.	Lucerne (*Medicago sativa*) var. Booborowie.
Guinea grass (*Panicum maximum*) var. ex Likoni, Mombasa.	Kenya white clover (*Trifolium semipilosum* var. *glabrescens*).
Nandi setaria (*Setaria sphacelata*).	Rueppells clover (*Trifolium rueppellianum*).
Molasses grass (*Melinis minutiflora*).	Burr Medic (*Medicago denticulata*).
Star grass (*Cynodon dactylon*).	Stylo. (*Stylosanthes gracilis*)
Beck grass (*Beckeropsis uniseta*).	(*Glycine javanica*).
	(*Alysicarpus rugosus*).
	(*Dolichos falcatus*).

A mixture of Cameroons Elephant grass and perennial *Dolichos* sp. nr. *D. lablab* was planted separately. The Star and Elephant grasses were propagated vegetatively. The legumes were all inoculated and this resulted in good nodulation except in the case of Lucerne.

Triple superphosphate was applied annually at 1 cwt. per acre. Sulphate of ammonia was applied during the last two seasons only at 1 cwt. per acre.

The pastures were grazed by cattle three to four times in each growing season and the residues were mown after each grazing to achieve uniformity in the sward.

Observations made on the grasses over the four-year period showed that the Nzoia variety of Rhodes was leafy and productive during the first season, but that it thinned progressively and had almost died out by the fourth year. Endebess Rhodes, on the other hand, maintained a persistent, productive, and well-knit sward during its four seasons.

Likoni Guinea grass, a rather stemmy medium-sized type having hairless leaves, was slow to establish in the first year, but it eventually formed a productive pasture which persisted well, although its tufts tended to become rather coarse and hollow in the centre. In common with many Guinea grasses it remained comparitively green during dry weather.

Nandi Setaria was rather slow to establish, but it formed a persistent vigorous sward which could probably have been kept in use for considerably more than four seasons. It is unfortunate that this grass tends to produce abundant coarse stems.

Molasses grass was quite quick to establish and grew vigorously during the first two seasons, but thereafter it began to thin out in the face of weed competition which became very marked in the fourth year.

Star grass was slow to form a sward and had to be weeded several times during establishment. It was less productive and less palatable than the other grasses throughout the four-year period.

Beck grass established quickly and gave a satisfactory yield of good quality feed for two years. It made erect leafy growth and produced stems much later than the other grasses. Its somewhat thin leaves wilted fairly rapidly during the dry weather.

Representative samples of four of the grasses, taken during July in the second year had the following composition:—

PER CENT OF DRY MATTER

Species	Crude Protein	Crude Fibre
Beck grass	14·74	31·03
Nandi setaria ..	13·19	34·35
Endebess rhodes ..	12·63	31·78
Guinea grass ..	11·96	37·01

The crude protein values are very satisfactory, but the Guinea grass is somewhat fibrous. The values shown for Beck grass are encouraging and it is possible that, having regard to its absence of stem and thinness of leaf, this species may be easily cured for hay.

Cameroons Elephant grass, planted in 6-ft. rows, was grazed simultaneously with the other species and persisted well. Its productivity and palatability were at least equal to the other grasses, and its greenness during dry weather was outstanding. Despite these good qualities it should be treated with some reserve, for not only does it require inter-row cultivation, but it is also difficult to eradicate. Apart from its importance as a mulch producer, it is potentially valuable for providing green feed during dry periods and should preferably be planted in separate stands outside the main ley/crop rotation area for this purpose.

Observations on the legumes showed that Booborowie Lucerne, an Australian variety, persisted rather weakly and was less productive than Kenya White clover or *Glycine*. This might have been due to the very high seed-rate used (15 lb./acre) and also to the fact that nodulation was unsatisfactory.

Kenya White clover was the outstanding legume. It flourished in combination with all the grasses and showed signs of becoming dominant in some mixtures, notably with Star grass and Guinea grass. The Nandi *Setaria*/Kenya White clover mixture was excellent.

Rueppells clover grew vigorously during establishment, and strongly dominated the grasses. It was slow and unreliable in its subsequent annual regeneration from seed and, in addition, its palatability was low. However, during its second season it had a noticeable beneficial effect on the associated grasses.

Burr Medic, although strong in the first year, was even slower and less reliable than Rueppells clover in its subsequent annual regeneration. This may be due largely to its hard seed pods which resist moisture penetration after the start of the rains.

Glycine javanica established well and persisted vigorously during the four seasons. It clearly benefited the grasses; the Molasses and Guinea grass mixtures being outstanding in this respect. The latter mixture showed good possibilities for grazing during dry weather owing to the drought resistance of both species. *Glycine* was less palatable than either Lucerne or Kenya White clover, but it was well grazed in the drier months. A seeding rate of 20 lb./acre was used, which is higher than would normally be possible on a farm.

Stylo combined quite well with all the grasses and was persistent and drought resistent, but its herbage was woody and unpalatable and its contribution was small in comparison with Kenya White clover.

Alysicarpus rugosus established rather poorly and, although scattered plants persisted for four seasons, their productivity and general performance was much inferior to that of Kenya White clover.

Dolichos falcatus, a perennial twiner which seemed promising in earlier trials, proved considerably less vigorous than *Glycine javanica*.

Dolichos sp. nr. *lablab* was only sown in combination with Elephant grass. It was established between the rows of grass and made good growth in the first season, but by the fourth year it had become almost non-existent.

REVIEW

A NEW VIRUS DISEASE OF PIGS

A new virus disease of pigs has been reported from Panama (Murnane, Craighead, Mondragon and Shelokov, 1960). The disease killed 30 out of 300 pigs in one feedlot over a 20-day period. Pigs in an adjacent feedlot were not affected. Deaths were sudden and rapid. The outstanding lesion found at post-mortem was severe myocarditis and heart failure was considered to be the primary cause of death.

The causative agent proved to be a virus which was identified by neutralization tests as encephalomyocarditis virus (EMC). It was pathogenic for mice, hamsters and guinea pigs and cytopathogenic for tissue cultures of primate and rodent cells. EMC has been isolated sporadically during the past 20 years from rodents and primates. Rats trapped on the premises possessed antibodies to EMC and were suspected as a possible source of the disease.

G.R.S.

REFERENCE

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PARASITIC INFESTATIONS OF ANIMALS

By Sir Thomas Dalling, Consultant of the Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

It is probably true to say that one of the greatest interferences with progress in improvement in animal production throughout the world as a whole, so far as animal health is concerned, centres round parasitic infestations. Parasites of one type or another are the cause of disease in animals in every country: the damage they do and the losses they incur depends very much upon conditions of animal husbandry and the application of measures for control based upon the knowledge of the habits and life-histories of the different parasites and on the use of agents at appropriate times to prevent infestations and to destroy the parasites in the animal body; the information now available has been the result of patient research work in different branches of science, including veterinary science.

It is impossible to assess the losses from parasitic infestations throughout the world or even in a single country with any degree of exactitude. Losses from deaths of parasitized animals may be ascertained but, in some parasitic infestations, much greater losses may occur from retarded development of the infested animals and from waste of food stuffs in keeping the animals alive instead of their utilization for normal or increased production. The time spent by animal owners and attendants in caring for and treating infested animals and the cost of medicaments have also to be taken into account and we must not forget that animals play an important part in the transmission of some parasites, during some stage of their life-history, to human beings. All these add up to a vast economic loss to countries and to individual animal owners.

In articles such as this, it is possible only to make brief reference to some of the important diseases caused by parasites, as illustrations of this complex subject and of the present state of knowledge.

Although some types of parasites exist and infest animals in all parts of the world, others are strictly confined to certain regions: climatic conditions have an important bearing on the life of some parasites and on the occurrence of vectors and the intermediate hosts required for completion of the life-cycles of some of the important parasites of animals.

Many varieties of worms infest animals and under certain conditions cause serious damage and losses in herds and flocks. With many, a state of tolerance on the part of infested animals may exist, whereby considerable numbers of worms may be harboured without any clinical evidence of disease. In some cases, infestations of the alimentary tract of young animals may be quite severe, but as the animals mature, tolerance develops and the worms, although still present and although re-infestation continues, do not appear to interfere to any marked extent with the adult animals' health.

In all species of domestic animals, the alimentary canal is the location of some types of round-worms: cattle, sheep, goats, pigs, horses and poultry harbour them. Some are almost exclusively confined to the stomach, some to the intestine, even to special parts of the intestine, while others overflow into several different regions of the tract. Generally speaking, the species of worms infesting the alimentary tract are specific for the type of animal: although the same species may occur in, for example, the stomach of cattle and sheep, there appear to be strain differences as shown by difficulty in cross-transmission.

All worms found in the alimentary tract are not similarly parasitic and disease producers: in this respect, the general finding is that the smaller the worm, the more damage it is likely to cause. Again, the different species of the worms have different life-histories and different treatments and control measures are required. Hence, it is necessary to identify the species of worm: this can be done only in the laboratory by experts in the subject who examine the worms and their eggs.

Life-histories or life-cycles of many of the worms, parasitic in the alimentary tract, have a considerable resemblance to each other. The females lay eggs which are passed out in the faeces and hatch out into larvae. The time taken to hatch depends upon the atmospheric and other conditions and may be only a few days. Again, the time taken for development of the larvae into the infective stage with the species and conditions. Eventually, the larvae in the infective stage are picked up by the susceptible animals and ingested into the alimentary tract, where they find their way to their selective location. In some species, the larvae penetrate into the walls of the stomach or intestine and remain there during their further development, emerging as sexually mature adults when egg laying takes place. The times occupied in the different stages of development have been studied for many species. In some, the eggs actually hatch in the intestine. Many of the parasitic worms are blood suckers; others, especially in the larval stages, cause damage to the lining membranes of the alimentary canal by irritation. It is usually only when large numbers of worms and larvae are present that actual parasitic disease is set up. Some species of worms infesting the alimentary tract have complicated life-cycles. One, infesting the pig, for example, requires an intermediate host, the coprophagous beetle. In one of the large worms in the pig, the eggs hatch in the intestine and the resulting larvae find their way to the liver where they undergo further development and are then carried to the lungs where they enter into the alveolar spaces through the capillary blood vessels. The adult worms may do some damage by blocking the intestine and even causing its rupture; they may also block the bile ducts. The larvae in the liver are the cause of "white spotted liver"; the condition in pigs known as "thumps" is due to the presence of these larvae in the alveolar spaces of the lungs. In the horse, one of the large worms infesting the large intestine is of much interest. Following ingestion, the larvae migrate into branches of the mesenteric arteries and cause aneurisms. Thrombi are produced and, because of their interference with the flow of blood to the intestine, colic ensues. From the thrombi, emboli may be released and may travel in the blood stream, eventually blocking some small blood vessels, the damage caused depending upon the organ or tissue in which the blockage occurs.

Although most of the infestations with worms of the alimentary tract take place through ingestion of the eggs or the larvae of the respective worms, some infestation may also occur through the skin.

Tapeworms also infest the alimentary tract. It is doubtful if many of them do extensive damage or cause actual disease. To some extent they must, of course, use up some of the available digested food in the intestine which might, otherwise be utilized by the host animal. All tapeworms have a complicated life-history in which intermediate hosts are necessary. The intermediate hosts of some are, as yet, unknown; others are well established, e.g. free-living orbatid mites for one of the tapeworms of cattle. Tapeworm infestations in domestic animals and man, are, however, often important because of the intermediate host. Thus, some tapeworms infesting human beings have cattle or pigs as their intermediate hosts in which the intermediate stage is found in the connective tissue of the muscles; some tapeworms of the dog require cattle, sheep, horses or pigs as their intermediate hosts in which they cause considerable damage. Examples are cysts, containing the developing worms, in the liver, lungs and muscular tissues of infested animals causing the condition known as hydatidosis, which also occurs in man and one which invades the brain and spinal cord of sheep, causing "gid" or "sturdy".

Round-worms are also parasitic in the respiratory tracts of cattle, sheep, pigs and horses. In each of the species of animals, different worms are involved: all give rise to verminous bronchitis. Lung-worm infestation in cattle is a very serious problem in some countries, while sheep also suffer to a considerable extent in some parts of the world. The infesting worms of cattle, sheep and horses all have a simple life-cycle. The adult worms in the air passages of the lungs produce eggs which are coughed up into the mouth and are swallowed. They hatch in the digestive tract and larvae are passed out in the faeces, where they develop into an infective stage within a few days under suitable conditions. When ingested in this stage, the larvae pass from the intestine into the lymphatic system and reach the lungs where further development into the adult stage takes place. In the pig, however, the life-cycle of the infesting worms is more complicated because various species of earth-worms are necessary as intermediate hosts. In some of the sheep-worms, also, intermediate hosts, snails or slugs, appear to be necessary for completion of the life-cycle. Cattle lung-worms cause bronchitis and typical bronchial pneumonia, while those of sheep cause typical lobar-pneumonia. This is an example of closely allied parasites, found in the tissue of different species of animals causing somewhat different types of disease.

Flat-worms are also important parasites of domestic animals. Tapeworms have already been mentioned. Another example is the liver-fluke, of which there are several parasitic species for domestic animals, including cattle, sheep, goats, pigs and horses. Human beings may also become infested and liver-fluke disease is common in rabbits, deers and some wild animals in some parts of the world. The common parasitic liver-flukes have an extremely complicated life-history. As the name indicates, the adults are found in the liver, where eggs are laid, pass to the intestine and so are passed out in the faeces. In many species, for further development, the eggs must be deposited near water so that the newly hatched stage can come into contact with the variety of snail in which several further stages can develop. Eventually, fully developed larvae escape from the snail and form into a resistant stage in which they may remain alive for many months. This stage is passed usually on aquatic plants and, when eaten by susceptible animals, become located in the alimentary tract. Here the larvae are liberated, penetrate the wall of the intestine, enter the liver through its surrounding capsule and live in the liver tissue where they eventually become adult and the cycle begins again. This is but a brief description of the highly complicated life-history and also illustrates the many risks to which the parasite is submitted during its life-cycle and before it can infest animals. There are several parasitic species of of liver-fluke, varying in size and different varieties of snails are required as intermediate hosts. Although many species of liver-flukes are associated with water snails, some require land snails.

Liver-fluke disease is the cause of heavy losses in some areas of the world where conditions exist for development of the parasite and the required snails. The disease is seasonal in character and the likely incidence can often be forecast from weather conditions at certain times of the year.

Some round-worms have peculiar selective locations in the organs of domestic animals. An example is a round-worm in the kidneys and the walls of the ureters of pigs, where eggs are laid and pass out in the urine. They soon hatch into larvae which become infective in a few days. On being ingested by pigs, the larvae pass through the wall of the intestine and migrate to the liver, finally finding their way to the kidneys and ureter where the adults develop.

Heart-worm infection in dogs, common in some countries, is another example. The adult worms live in the right ventricle of the dog's heart, where they may remain for several years. Eggs actually hatch in the female worm's uterus from which the embryos pass into the blood stream of the dog and may remain there for long periods. Intermediate hosts, in the form of insects, e.g. mosquitos, are necessary for further development of the parasites into the infective larvae which travel to the mouth parts of the biting insect: the infective larva is transmitted to the bog by bites of the insect.

Another example is the parasite which causes trichinosis in man and some animals. Part of its life-cycle is passed in the form of an encysted larva in the striated muscles, common sites being the diaphragm, tongue and intercostal muscles. Such uncooked infected meat is the source of infection for man and animals, wild and domestic, like carnivors and pigs. Rats, wolves and foxes are also infected. The encysted larva is liberated in the small intestine of the animal consuming the infected meat and soon becomes mature there. The fertilized female penetrates the lining of the intestine and produces living larvae, which are carried by the blood and lymphatic systems to the various organs and tissues where they become encysted.

There are many external parasites of domestic animals. Various species of flies are parasitic and may, in addition to causing damage by annoyance and loss of blood, convey mechanically the casual agents of some infectious diseases. Horse-flies (*Tabanus*) which, except in the adult stage, are aquatic or semi-aquatic, lay their eggs near water and the young larvae find food in the water and mud, where they may remain for long periods before pupating in drier soil. Some species of mosquitoes have been known to attack livestock in such large numbers as to cause actual death, but more commonly, lowered production. A most interesting part is played by a species of the mosquito in the transmission of the condition "torsalo" in some South and Central American countries. The fly *Dermatobia hominis,* fastens its eggs to the mosquito. As the mosquito feeds on cattle, the eggs hatch and the liberated larvae bore into the skin and cause much irritation and damage, often resulting in the death of the infested animal if treatment is delayed.

Mosquitoes are also known to convey the virus of fowl pox.

Stables flies and horn flies are blood suckers and may account for some anaemia in attacked livestock, when excessive numbers infest them over a period.

Ox warble flies, of which there are two main species, *Hypoderma lineatum* and *Hypoderma bovis,* are important parasites because of the damage their larvae causes in the hides of cattle and buffaloes. The eggs are fastened to the hairs of the leg and lower parts of the body. Hatching takes place in a few days and the larvae burrow directly into the skin. They then travel into and through various parts of the body, apparently through the connective tissue in which they have been found in many organs. The routes taken by the larvae of the two species seem to differ, but eventually both arrive in the connective tissue of the back where a breathing pore is made and the typical "warbles" develop. After some weeks, the warbles squeeze through the pores and fall to the ground where they pupate and become adult flies in a month or two. The life of the adult flies, which do not feed at all, is only a few days.

The larval stages of several species of blowfly infest the wool and skin of sheep. Although wool soiled by faeces, attracts the flies to deposit their eggs sometimes, in the absence of any soiled wool, specially in wet or moist, hot weather, the infestation takes place. The maggots hatch out from the deposited eggs, attack the wool and, if not controlled, feed on the skin and even the flesh. Failure to attend to infested sheep may mean a considerable death-rate in some seasons. In addition to sheep, the flies may use carrion of various kinds in the completion of their life-cycle.

The sheep nostril fly is troublesome in some areas. Living larvae are produced and are quickly deposited near the nose, from where they find their way into the nasal passages of the sheep where they develop and may remain for long periods. Eventually, the fully developed larvae leaves the nose, falls to the ground where pupation takes place followed, in due course, by the adult stage.

Very heavy losses may follow screw-worm infestation of livestock in parts of America. Screw-worms are the larvae of a species of blowfly. Adult flies deposit eggs at the edge of a wound: the eggs soon hatch and the resulting larvae enter the wound and become buried in the animal's flesh, where they feed on the living flesh and complete this stage of development in a few days. On reaching the ground pupation takes place with eventual development of adult flies. The time taken to complete the life-cycle may be a few weeks or longer, depending upon the climatic and other conditions.

Infestation of livestock with the various species of ticks may cause heavy losses. In addition to the important diseases which ticks transmit and which will be discussed in a later article, ticks themselves cause losses in production from the irritation they set up, from the removal of blood during their feeding and from abcess formation in the infected hosts. The sheep ked, sometimes erroneously called a tick, passes its entire life-cycle on sheep. Each female ked produces only one fully-developed larva at a time and during her life about 15 may be deposited. Losses from infestation by keds are caused by irritation, interference with wool growth and removal of blood during feeding.

Lice are common on the different animal species, including poultry; eggs are fixed to the hairs or feathers and in a few weeks a new generation of lice is evolved.

All species of livestock are liable to be infested by mites, which cause mange or scabies. Although the species of the infesting mites are very similar in all animals, the actual variety of the species differs in the various types of animals. The three important manges are sarcoptic, sporoptic and chorioptic, each caused by different species of mites. In horses and pigs sarcoptic mange is the most severe, but the other two also occur; while in sheep it is generally the psoroptic mite which causes scabies or sheep scab. In many countries, scabies in horses and sheep is a notifiable disease and the treatments officially applied have resulted either in eradicating the diseases or in reducing the incidence to a marked extent.

Another mange, demodectic mange, also caused by a variety of mite, occurs in most types of domestic animals, but except in dogs it is relatively rare. The responsible mite is found in the hair follicles and sebaceous glands of the skin where it gives rise to much irritation.

Fungi also infest the skin of domestic animals and human beings, causing the condition popularly known as ringworm. The types of the responsible fungi vary with the animal, but their method of infestation is very similar and the same variety may be transmitted to another type of animal, including man. Following invasion of the hair and the external parts of the skin, thread-like structures develop and enter the hair folicles where many resistant spores are produced. The infection spreads in a circular manner; hence the term "ringworm". Ringworm is found mostly in the winter months in housed animals, e.g. calves, the fungus surviving in the stables from year to year. White comb disease in poultry is also caused by fungus.

Some of the parasitic diseases of animals are caused by protozoa, which are small single-celled members of the animal kingdom. Within the various classes, subclasses, orders and families there are many species, some of which are of much importance as causes of disease in human beings and animals. The diseases caused by them arise from damage to the cells and tissues of the infected animals' hosts and, to some extent, from utilization of already elaborated food substances in the animal and from interference with metabolism. The virulence of the various strains of a species may vary considerably, so that the symptoms produced in the infected animal may be acute, with death early after infection, or a chronic type of disease may be set up, with eventual recovery. In many of the diseases caused by protozoa complete cure may not be effected but a state of resistance is established: this is known as "premunition", a state in which the protozoan parasites are still present in the host and a balance exists between them and a developed immunity. Sometimes, when animals in a premune state are exposed to what is termed "stress", e.g. travel over long distances, insufficient food or too much work, the parasites assume renewed activity and symptoms of the specific disease again appear. Transmission of many of the protozoan parasites from infected to healthy, suceptible animals is effected by vectors—ticks and insects. In some, transmission may be entirely mechanical, the vector simply transferring the parasite from one animal to another; in others, however, the parasite has a complicated life-cycle in which the vector plays an important part. There is high selectivity of vectors for particular protozoan parasites, special species of ticks and insects being required to complete life-cycles and so to act as transmitters of the infective agent. In the completion of their life-cycles, protozoan parasites undergo many risks and it is sometimes difficult to appreciate how, in spite of all the risks, the parasites continue to survive and develop in such numbers as to cause extensive outbreaks of disease. The distribution of disease-producing protozoa throughout the world varies considerably, depending to a large extent on climatic conditions upon which also depends the existence of the vectors. Many investigations have been carried out by research workers, including veterinarians, on protozoan infections in animals, including methods for their control and eradication. In this article, it is possible only to discuss some of the diseases most commonly found in different parts of the world with special reference to some of the specific characteristics of their occurrence, transmission and control. It is not the purpose of this article to consider details of the many advances made in our present knowledge of this extensive subject and in the methods adopted for control of the different diseases: the objective is rather to draw attention to the importance of protozoan infections of animals and to show how veterinarians throughout the world are applying the results of research work in dealing with them.

Coccidia are protozoa, found in all parts of the world some of which cause the disease *coccidiosis* in practically all species of animals, except horses. The disease is commonly found in fowls and turkeys. There are many species of coccidia but they are largely host specific, i.e. species infecting one type of animal or bird do not normally infect other types: several species, however, may infect one type of animal or bird, and some are more dangerous than others. *Coccidiosis* is found much more commonly in young animals and birds than in adults. This is related to the immunity which follows infection and the fact that most animals and birds are exposed to the infection during their young ages. Severe outbreaks, however, may occur in adults which have escaped this exposure in earlier life. It is during the completion of their life-cycles that the parasites do damage, the number of parasites ingested by the host determining the extent. Small numbers do not cause coccidiosis but rather give rise to an immunity: massive infection, however, causes coccidiosis, sometimes with very heavy losses. In chickens, for example, the coccidium which infects the caecum may well cause deaths of 80-90 per cent of a group exposed to heavy infection. In nearly all infected animals and birds, the parasite invades the cells of the intestine, and the amount of damage done to them determines the acuteness of the infection. Different species of coccidia show preferences for different parts of the intestine: this is specially marked in fowls in which several species set up coccidiosis, one infecting the caeca of young birds often with disastrous results. The life-cycle of coccidia is complicated. A careful and detailed study has been made of one of the species infecting fowls. Briefly, the life-cycle is as follows: mature forms develop in the intestine and are passed out in the faeces and develop into a resistant form on the ground, which may remain inactive for weeks or months. In continued exposure to dryness, low temperature and lack of oxygen, further development may be completely inhibited. Under suitable conditions of warmth and moisture division of the parasite takes place within the resistant stage, the final number of elements varying with the species. On being ingested these elements are liberated in the intestine and invade the cells of the lining membrane where further development and multiplication takes place. They become freed from the intestinal cells and invasion of new cells and further multiplication may be continued over generations: it has been shown that the greatest damage is probably done by the second generation which penetrate more deeply into cells of the lining membrane. Eventually, a differentiation of the coccidial elements takes place whereby male and female elements are formed; many females, few males. The female elements are fertilized and mature coccidia are produced and the life-cycle is continued. In preventing coccidiosis note has to be taken of the degree of infection to which the hosts are exposed. The more intensively animals and birds are kept the more likely is massive infection to occur. No matter how many precautions are taken it is impossible to remove *all* coccidia from an infected premises or area. The object should be to so reduce the numbers that mass infection cannot occur and that the numbers are such that only light infections, leading to the development of immunity will take place.

Babesiosis or *piroplasmosis* is caused by protozoan parasites which invade the red blood corpuscles. There are many species of the parasite, each of which is host-specific: in some species of animal more than one species of the parasite cause disease, the largest types usually being the most virulent. Piroplasms are responsible for cattle tick fever, redwater in cattle, piroplasmosis in horses, piroplasmosis in sheep, piroplasmosis in pigs and piroplasmosis in dogs. Many of the diseases are confined to tropical or subtropical regions while others have a wider geographical distribution. Ticks are the vectors of piroplasms, the species of ticks involved varying with the actual species of the parasite. Part of the life-cycle of the piroplasm is spent in the tick host but direct transmission by the injection of blood from an infected animal into a suceptible animal of the same species can be effected. The life-cycles of some piroplasms have been well studied; the following is a typical example. The piproplasms multiply within the red blood cells of the infected animal and infect other cells. Infected blood is ingested by the tick while feeding and the complicated life-history begins. Within the tick some further development takes places and the resultant stage passes through the intestinal wall of the tick, eventually invading the ova where growth takes place. New forms are produced and migrate through the embryonic tissue cells to the salivary glands where, again, further development occurs and, finally, there results a piroplasm in a form which infects susceptible hosts when injected by the tick during feeding. In such a life-cycle, the infection passes through the egg of the tick and infection is carried out by the next generation. In the absence of susceptible hosts it is believed that piroplasms may persist through several generations of ticks. Susceptibility of animals to piroplasmosis seems to increase with age, young animals being mostly resistant. It sometimes happens that, although piroplasmosis may be enzootic in an area and there are ample opportunities for its occurrence, it is only when susceptible adult animals from a free area are introduced that the disease becomes evident. Symptoms of piroplasmosis vary in intensity, the most acute being commonly found a few days after infection has taken place, this being the time when large numbers of the parasites are present in the blood. A state of premunition in infected animals is characteristic of piroplasmosis with a persistent low-grade infection and a considerable degree of resistance to reinfection. The resistance may, however, be broken down because of some form of stress and then symptoms of piroplasmosis again become evident. Outbreaks of piroplasmosis in cattle commonly follow the movement of adult susceptible stock into an enzootic area or the movement of tick-infested stock carrying the parasite into clean tick-free areas.

Some species of piroplasms respond to drugs injected into the infected animal and in some countries in which the incidence of the disease in cattle is relatively low, such drug treatment is largely practised. Again, because young animals are less susceptible than adults, premunition is practised with some species of piroplasms in cattle and horses in some areas: blood from adult cattle carrying the specific infection is injected, careful watch being kept on the injected animal to observe any severe reaction when drug treatment must be quickly given. Large-scale control of piroplasmosis, however, depends on tick control. Although this is beset by many difficulties, that it can be done and is followed by the eradication of piroplasmosis, is shown by the work in the United States of America where, at ont time, 14 States were heavily infected and where the disease has been practically eradicated following systematic dipping of animals to destroy the important tick vectors. Ticks have interesting life-cycles. The engorged fertilized female lays eggs in some sheltered spot on the ground: the eggs develop, sooner or later according to weather conditions, into six-legged larvae which, after feeding and moulting become eight-legged nymhpae; in turn, they develop into adults, male and female. Ticks can be grouped according to one of the aspects of their life-cycle, viz. (*a*) a one-host tick, in which all the stages are passed on a single animal, the fertilized female finally dropping off to lay eggs; (*b*) a two-host tick, in which the larval and nymphal stages are passed on one animal and the adult stage on another; (*c*) a three-host tick, in which each stage, larval, nymphal and adult are passed on different animals. In one-host ticks, transmission of the piroplasm takes place through the egg; with the other ticks, the parasite may be carried only from stage to stage of development. In dipping schemes for the control of ticks, a knowledge of these host habits is essential so that the time during which the tick in any of its stages may remain on a host animal is known. Much good work is in progress in controlling ticks in many parts of the world by dipping and spraying. Large-scale operations are being carried out in which compulsory dipping is practised at regular short intervals. More efficient spraying machines are being evolved, especially for use by individual farmers. New ticides are being used and others tried out. Some difficulties, however, are being experienced because of the development of a resistance by some species of ticks to one or several of the ticicides. Alternating the agents used in dips and sprays is being practised as a temporary measure to overcome this resistance. Veterinarians in many parts of the world are actively engaged in tick control work and are well acquainted with the work involved in carrying out extensive programmes.

Another group of protozoan parasites is included in the genus *Theileria,* of which several are important causes of diseases known as *theileriasis,* one of which is East Coast fever in cattle with high mortality in Central and South Africa. Other diseases caused by *Theileria* occur in some parts of tropical and subtropical Africa, in Asia and in parts of Europe. A recently discovered species has been named as the cause of Corridor disease in cattle in Zululand. Sheep and coats also suffer from infection with *Theileria,* specific to the species.

The life-cycle of the parasite which causes East Coast fever has been worked out. Definite species of ticks are the vectors of the infection. The infective stage of the parasite is found in the saliva of infected ticks, and is injected into the cattle host when the tick feeds. The parasites travel in the lymphatic system to lymphatic glands and other lymphatic tissue where they enter lymph cells and increase in size and form elements known as Koch's blue bodies, the presence of which is recognized as diagnostic of the disease. These bodies eventually become free in the lymphatic fluid and, after some further development, invade the red blood corpuscles from which they are ingested by the tick. When ingested by the tick in its larval or nymphal stages, the parasites congregate in the intestine where still further development takes place and eventually the infective stage finds its way to the salivary glands of the next stage of the tick, ready to be injected into the host. Cattle which recover from East Coast fever are solidly immune against reinfection, and do not harbour the parasite: ticks fed on recovered animals do not transmit the infection to susceptible cattle. With infections with some other species of *Theileria,* however, recovered animals develop a state of premunity and remain carriers of the parasite. The incidence of East Coast fever depends to a large extent on the incidence of the vector tick: up to 80 per cent of the calf crop may die every year from the disease in some enzootic areas. Some success has resulted from the treatment of infected animals with newer types of drugs: the only sure method of controlling the disease, however, will be by the practice of tick control on an extensive scale.

Anaplasmosis of cattle, termed Gall sickness in Africa, is another disease caused by a protozoan parasite, *anaplasma,* which is widely distributed and causes infections in cattle throughout the tropics, in Africa, in the warmer parts of America, in the Near East, in some parts of Europe and in the Far East. Although the life-history of the casual protozoan parasite is not yet well understood, it is known that several species of ticks and insects, including mosquitoes, can transmit the infection. This parasite of cattle does not appear to cause disease in sheep or goats. A species of anaplasma, not highly pathogenic for cattle, is used to a considerable extent in some countries in the protection of cattle against true anaplasmosis. The injection of blood of cattle, carrying this species, into cattle susceptible to anaplasmosis, preferably in their young ages, prevents the development of clinical symptoms of anaplasmosis on their later exposure to the infection. Although anaplasmosis has been described as occurring in sheep, goats, horses, donkeys, swine and dogs, little detailed information is available.

The family *Trypanosamidae* with its various genera, is of much importance in veterinary medicine: it contains a large number of protozoa parasitic in animals, many of which cause severe losses in different parts of the world. The genus *Trypanosoma* is of outstanding importance. While ticks are largely responsible for the transmission of the protozoan parasites already mentioned in this article, flies are the vectors of many of the species of this family. It is not possible to refer here to all the parasites and diseases caused by them; a few notes and examples will suffice to illustrate their importance.

Trypanosomes are parasites of the blood and other tissues. Although some species cause much disease in cattle in the African continent mainly in regions where the tsetse fly is present, other species which do not require this fly for their transmission cause infections in Africa and in other parts of the world. Different species, sometimes more than one, infect different types of animals. Some species, although commonly found in animals do not appear to cause any harmful results. Many species of wild game also harbour trypanosomes without any evidence of disease.

The virulence of different species and the same species of trypanosomes varies. In Africa the disease of cattle, Nagana, is an example of such variation with resultant differences in its acute or chronic characters. The relationship between Nagana and the occurrence of the tsetse fly in Africa is well established, large areas in the tropical regions of the continent being devoid of cattle because of the presence of the tsetse fly and the trypanosomes transmitted by it. While this relationship is well recognized, some species of the trypanosomes so transmitted have been found in other parts of the world where this fly does not exist. Some disease-producing trypanosomes do not require flies for their transmission: a typical example is the species causing dourine in horses, a disease at one time prevalent in many countries and now largely limited to specific areas, in which the most common method of transmission is through the genital tract. With some trypanosomes, species of flies act merely as mechanical carriers, e.g. in the disease Surra in horses and camels. Trypanosomes, transmitted by the tsetse fly have a complicated life-cycle. Infected blood is taken into the intestine of the fly when feeding: many disappear, but those remaining multiply there. They then either are passed out in the faeces of the fly on to the skin of cattle or they migrate forward and invade the mouth parts of the fly where they undergo further development and eventually are injected in an infective form into cattle. The African species of trypanosomes normally transmitted by tsetse fly can also be transmitted mechanically by biting flies. They are infective immediately after feeding on an infected animal and remain infective only for a short time. Tsetse flies may also act as mechanical transmitters.

Reservoirs of infection are important in the transmission of trypanosomes. In Africa, for example, it is probable that wild game harbour the infective parasites: parasites causing surra in horses and camels may be harboured by cattle and buffalo without causing any evidence of disease in them.

Several measures are being applied for the prevention and control of trypanosomiasis. Some drugs are found to give satisfactory results under certain conditions. The eventual development of the resistance of the parasites to drugs is, to some extent, a limiting factor in their use.

So far as present information goes, it would seem that the total eradication of trypanosomiasis by drug treatment of cattle is probably not possible. It is seldom now that any treatment is applied for dourine in horses: when infection is diagnosed, the affected animal is destroyed. In Africa attempts have been made to develop resistant breeds of cattle. Much attention is being given to the ecology of the tsetse fly with a view to evolving practical methods for its control. The use of repellants to protect cattle on grazing grounds has not proved satisfactory because their effect is very short-lived. Spraying from the air has also been used, as well as cattle sprayed with an insecticide to attract and kill the fly. De-flying houses on the main traffic routes has also been tried. The most satisfactory results are obtained by bush clearing. This eliminates the tsetse fly and a barrier of about half a mile has been found greatly to reduce the chances of cattle being attacked by the fly. In tropical regions, however, the very rapid regeneration of bush has to be considered. Attention has also been given to biological methods of control including the release of male flies of an incompatible race and sterile males of the same race. Game control is also of importance.

Trichomonas is another genus of protozoa of some considerable importance in veterinary medicine. Some species of trichomonads infect fowls, turkeys and pigeons, one of which is passed directly from the mother pigeon in the pigeon-milk fed to the young squabs, causing a considerable death-rate. The species *Trichomonas foetus* is the cause of a specific venereal disease of cattle, in which infertility and abortion are the prominent symptoms. The protozoan parasite inhabits the preputial cavity of the bull and is found throughout the genital tract in cows. The infection is transmitted direct from the bull to the cow, from the cow to the bull, and from cow to cow by the bull, during mating. It may also be conveyed to cows during manual examination and instruments which may become infected from a previously examined diseased cow. Infected bulls used for artifical insemination may be the source of spread throughout many herds. Trichomoniasis is known to occur in practically all parts of the world. Self cure takes place in breeding herds in that if breeding is suspended until three normal oestral periods have passed, it can usually be accepted that the infection no longer exists in the animal. While some progress has been made in effecting cures of infected bulls, the most general view, at present, is probably that in the control of the disease, infected bulls should be slaughtered. While the use of artificial insemination with semen from healthy bulls is of much value in preventing spread of trichomonas, the damage done by an infected bull used for this purpose can be well understood. Although the infection may be entirely eliminated from an infected herd, some recovered animals may be completely sterile and much loss of time in production will have been experienced with consequent financial loss.

A species of the protozoan parasite, Histomonas, causes infectious entero-hepatitis, commonly known as "blackhead" in turkeys, domestic fowls and some other birds. *Histomoniasis* is essentially a disease of young turkeys, the great majority of which die if infected when less than one year old. Chickens are more resistant. The method of infection with this parasite is interesting. The parasite is carried within the eggs of the nematode worm *Heterakis gallinae*, commonly found in the caeca of turkeys and chickens, from which it reaches the liver where it produces the characteristic lesions of the disease. In all probability, nearly all these worms carry the infection and the disease is often conveyed from the more resistant chicken to young turkeys. Control of histomoniasis consists in improved husbandry, including regular treatment for control of the worms and preventing contact of young turkeys with other poultry. Some arsenical compounds appear to be of value in treatment of the infected birds.

There are many other protozoan parasites of interest to veterinary medicine, but the examples given in this article are probably some of the most important.

It can be seen that many of the parasitic infestations present complicated problems, including their control. It is not the intention of this and other articles in this series to dewll upon the methods of control of animal diseases. Veterinarians throughout the world are well acquainted with the problems and with methods of control, based on the results of research work and experience; they should be consulted and their advice followed. Animal and pasture managements have considerable bearings on the control of some of the infestations and the use of medicaments externally and internally, occupy an important place in preventing them and in the treatment of infested animals.

THE APPLICATION OF A PHOSPHATE FERTILIZER ON DIFFERENT CROP ROTATIONS IN KENYA

By **E. Boswinkle, Department of Agriculture, Nairobi, Kenya**

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Although the available information on the fertilizer requirements of soils and crops in Kenya is expanding, and widespread economic benefits from the application of phosphates (1, 2) have been established, very little is known about the fertilizer requirements of crop rotations and local knowledge is particularly scanty regarding the crop sequences and the points in these crop sequences to which phosphate fertilizer should be applied to achieve the greatest benefit.

Accordingly, in 1956, a number of trials were undertaken at different centres in Kenya Colony, in which various sequences of three arable crops, of importance in each of the areas, were combined with different subdivisions of a uniform practical dressing of double superphosphate.

The trial reported here was laid down in the Kenya Highlands at Sotik, using a total dressing of 210 lb. double superphosphate per acre over the three years to various sequences of maize, wheat and English potatoes. Sixteen fertilizer—crop sequence treatments were selected and combined in five replicates of a (4 x 4) balanced lattice square. The soil on the site was, quoting Woodruff (3), a deep and dark reddish brown friable clay derived from andesite.

A summary of yield results for the three years, as lb. per acre, is presented in table I. It is immediately apparent that these results were greatly influenced by seasonal effects. in particular on potatoes.

The possible significance of this is discussed later.

From the yield data the gross profit return (after deducting the cost of the fertilizer) and the gross starch-equivalent (s.e.) production per acre were calculated. The cash return estimate is of direct concern to the farmer who is growing crops directly for profit whereas the starch-equivalent production is of concern to peasant producers growing crops mainly for the subsistence of their families.

In determining the gross profit per acre, the value of wheat on the farm at Sotik was taken as East African Shillings (Sh.) 50 per 200 lb. bag, potatoes at Sh. 19 per 180 lb. bag, maize at Sh. 27 per 200 lb. bag and double superphosphate at Sh. 81/70 per 2 cwt. bag. The starch-equivalent was taken as 18 per cent for potatoes, 77.6 per cent for maize and 71.6 per cent for wheat.

The gross profit returns in Sh. per acre and starch-equivalent returns per acre are tabulated in table II for the various crop rotations roughly in order of decreasing magnitude, with their significance levels. Where applicable, significant differences are indicated by the arrows within each group of (identical) crop rotations.

TABLE I.—SUMMARY OF YIELDS, AS LB. PER ACRE

1956			1957			1958		
Crop	lb.*	lb./acre	Crop	lb.	lb./acre	Crop	lb.	lb./acre
Potatoes	(210)	9,572·5	Maize ..	(0)	2,973·9	Wheat ..	(0)	381·3
Potatoes	(105)	10,696·9	Maize ..	(105)	2,989·0	Wheat ..	(0)	459·6
Potatoes	(70)	8,438·2	Maize ..	(70)	3,019·1	Wheat ..	(70)	312·9
Potatoes	(210)	9,640·9	Wheat ..	(0)	713·8	Maize ..	(0)	3,277·5
Potatoes	(105)	8,301·4	Wheat ..	(105)	645·3	Maize ..	(0)	3,677·7
Potatoes	(70)	8,888·0	Wheat ..	(70)	518·2	Maize ..	(70)	3,589·6
Maize	(210)	1,611·8	Potatoes ..	(0)	2,581·3	Wheat ..	(0)	449·8
Maize	(105)	1,493·7	Potatoes ..	(105)	4,067·6	Wheat ..	(0)	391·1
Maize	(70)	1,507·5	Potatoes ..	(70)	3,471·1	Wheat ..	(70)	420·4
Wheat	(210)	860·4	Potatoes ..	(0)	2,669·3	Maize ..	(0)	3,562·5
Wheat	(105)	1,095·1	Potatoes ..	(105)	3,617·8	Maize ..	(0)	3,243·7
Wheat	(70)	1,378·7	Potatoes ..	(70)	4,116·5	Maize ..	(70)	4,105·3
Maize	(105)	1,973·1	Wheat ..	(105)	606·2	Potatoes ..	(0)	5,651·6
Maize	(70)	1,465·9	Wheat ..	(70)	479·1	Potatoes ..	(70)	8,985·8
Wheat	(105)	1,036·4	Maize ..	(105)	3,056·7	Potatoes ..	(0)	5,876·5
Wheat	(70)	958·2	Maize ..	(70)	3,101·9	Potatoes ..	(70)	8,213·4

* = lb. double superphosphate per acre.

TABLE II.—SUMMARY OF RESULTS, GROSS PROFIT AND STARCH-EQUIVALENT

Rotation	Gross Profit Sh./acre	Starch-equivalent
Potatoes (210) Wheat (0) Maize (0)	1,581	98·5
Potatoes (105) Wheat (105) Maize (0)	1,452	95·5
Potatoes (70) Wheat (70) Maize (70)	1,544	103·5
Potatoes (210) Maize (0) Wheat (0)	1,469	90·6
Potatoes (105) Maize (105) Wheat (0)	1,533 } 5%	92·1
Potatoes (70) Maize (70) Wheat (70)	1,280 }	81·8
Wheat (105) Maize (105) Potatoes (0)	1,225	85·7
Wheat (70) Maize (70) Potatoes (70)	1,384	86·9
Wheat (210) Potatoes (0) Maize 0)	903 }	81·4 }
Wheat (105) Potatoes (105) Maize (0)	1,014 } 5%	82·1 } 5% } 5%
Wheat (70) Potatoes (70) Maize (70)	1,231 }	97·7 } }
Maize (105) Wheat (105) Potatoes (0)	898 } 1%	35·5 } 5%
Maize (70) Wheat (70) Potatoes (70)	1,261 }	70·0 }
Maize (210) Potatoes (0) Wheat (0)	544	43·5
Maize (105) Potatoes (105) Wheat (0)	643	41·7
Maize (70) Potatoes (70) Wheat (70)	630	45·3
Mean	1,162	78·2
Least significant differences:		
5%	247	12·5
1%	333	16·9
0·1%	442	22·4
Coefficient of variation	16·5%	12·4%

Study of this table shows that the number of actual significant differences within each rotation—i.e. differences which are attributable to the distribution of the double superphosphate, are comparatively few indicating that the manner of application of the fertilizer is relatively unimportant.

This is clearly brought out in table III which shows that there are no differences of importance between the various fertlizer sequences either in respect of gross profit or of starch-equivalent.

TABLE III.—MEANS OF FERTILIZER RATES
(MEANED OVER ALL ROTATIONS EXCEPT WMP AND MWP)

Fertiliser Rates	Gross Profit per Acre	s.e.
	Sh.	
210 — 0 — 0	1,124	78·5
105 — 105 — 0	1,160	77·8
70 — 70 — 70	1,171	82·1
Mean	1,152	79·5
Least significant differences:		
5%	124	6·3
1%	166	8·4
0·1%	221	11·2

On the other hand, the means of the rotations (table IV), differ markedly. Obviously, the biggest profit resulted from using potatoes as the breaking crop and a somewhat greater (though non-significant) return was obtained from following the potato crop with wheat rather than maize. Breaking the land with maize, on the other hand, gave the poorest return particularly if potatoes were planted in the second year.

TABLE IV.—MEANS OF ROTATIONS
(*Averaged over* 105–105–0 *and* 70–70–70 *fertilizer rates*)

Rotation	Gross Profit per Acre	s.e.
	Sh.	
Potatoes–Wheat–Maize ..	1,498	99·5
Potatoes–Maize–Wheat ..	1,407	87·0
Wheat–Maize–Potatoes ..	1,305	86·3
Wheat–Potatoes–Maize ..	1,123	89·9
Maize–Wheat–Potatoes ..	1,080	62·8
Maize–Potatoes–Wheat ..	637	43·5
Mean	1,174	78·2
Least significant differences:		
5%	175	8·9
1%	235	11·9
0·1%	312	15·8

Considering the possible effect of season on these conclusions, table I shows that years 1956 and 1958 were much better potato years than 1957 and provided the crop got 70 lb. of double superphosphate in the third year of the crop sequence, it yielded quite as well as when it was planted as the breaking crop, with the same phosphate dressing. The decrease of the potato yield in 1957 had a decisive effect on the profitability and start-equivalent production of the rotations in which potatoes were the second crop after breaking.

On the other hand, when maize was taken as the second crop, it yielded much heavier than when it was taken as the breaking crop while it actually gave the highest yields in the third year. The poor yield in the breaking year is in line with general farm experience and confirms the inadvisability of breaking grass straight into maize. The excellence of maize in the third year suggests that there is a certain flexibility regarding when it can be planted after the first year of the rotation.

The best yields of wheat were in 1956 and only in that year were they high enough to be of economic interest. They declined progressively in the next two years, becoming virtually a failure in 1958. If this decline in wheat yields over the years is a rotation rather than a season effect, it would seem that Sotik farmers wishing to grow wheat should grow it in the breaking year.

As a result of this information, further experimentation is needed covering a new range of seasonal conditions with a selection of rotations preferably on a series basis.

SUMMARY

1. Potatoes are better than maize for breaking land at Sotik.
2. Either wheat or maize can follow potatoes with equal success provided that the breaking crop of potatoes is given the complete dressing of phosphate, or the maize as well as the potatoes receives a dressing of the fertilizer.
3. The least satisfactory of the rotations is maize—potatoes, wheat, whatever the distribution of the phosphate fertilizer.
4. Fertilizing maize and potatoes at Sotik is more beneficial than fertilizing wheat.
5. The conclusions although based on a single crop cycle and a single season are supported by observations on other fertilizer trials and are considered to be of wide application in the Kenya Highlands.
6. If some wheat is to be grown at Sotik, it is best grown in the first year.

ACKNOWLEDGEMENTS

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RAPID PROPAGATION OF SISAL HYBRID No. 11648

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The normal plantation method of propagating sisal vegetatively, is by the use of basal suckers or bulbils. Where it is desired to bulk up rapidly one particular plant, such as hybrid No. 11648, the use of single rhizome buds greatly speeds the task of multiplication.

The rhizomatous stems bearing these buds are found radiating out from the bole of the plant, usually six to nine inches below ground. In the case of a plant more than a year old numerous stems are formed, and the apical bud often appears above ground two or three feet away from the parent. At intervals of one inch or more, buds are formed on these underground stems. The apical bud appears to be completely dominant, and until such time as this bud dies or becomes detached from the stem, the remaining buds do not develop.

Once the apical bud is removed from the stem, as in the field operation of suckering, the next bud immediately behind ceases to be dormant, swells and develops into a plant. Again, it appears this bud becomes dominant, and the remaining buds on the stem fail to develop. If, however, the rhizome is removed from the parent plant and cut into single bud pieces, all these buds, if planted, shortly commence to develop.

In the case of hybrid No. 11648, rhizomatous stems some 12-14 inches long have been removed from one year old plants. These yielded 8-10 single buds per stem; within eight weeks of planting, more than 90 per cent of these single buds had developed into plants four to six inches high under laboratory conditions. In a field nursery, the percentage "take" is about 70 per cent. Prior to planting, some buds were treated with various root promoting hormones, also fungicide. In all cases the untreated buds grew quicker, and gave a higher percentage of "takes".

In practice it has been found preferable to plant these rhizome sections at a close spacing (10 x 10 cm.). The buds are inserted upright in a well prepared nursery bed just below soil level. A mulch of well rotted sisal waste about 1-1½ inches thick over the nursery bed is advisable. During dry weather, daily watering of these beds is necessary, otherwise no special treatment is required. When the plants are 4-5 inches tall they should be transplanted into a normal nursery at the usual spacing of 25 x 50 cm.

SMALL SCALE EGG PRODUCTION IN UGANDA

By J. C. M. Trail, Livestock Experimental Station, Entebbe, Uganda

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In view of the apparent trends towards lower profit margins as the poultry industry develops in Uganda, it is essential that the farmer endeavours to run his unit as efficiently as possible. With careless management, poor stock or improper feeding, it is difficult to avoid incurring a loss.

Up to the present time no detailed work has been carried out to determine the cost of production of eggs from small scale poultry units, and the probable profits or losses have been very largely a matter of conjecture.

This trial was commenced in February, 1959, to obtain accurate records from a group of Rhode Island Red pullets housed in a fold unit for one laying year.

METHOD

Twenty-two point-of-lay pullets and three cockerels of the Rhode Island Red breed were obtained from the commercial stock offered for sale by the Livestock Experimental Station, Entebbe, and housed in a fold unit designed and tested on this station, and recommended to African farmers. The birds were maintained for one year; accurate records being kept of egg production, food consumption, labour, mortality and culling. The unit was run for the production of hatching eggs and from the data obtained the costs of production of both hatching eggs and table eggs were calculated.

The fold unit was under the charge of an African poultry attendant, and the management was equivalent to that of an average African poultry farmer. The unit was moved to clean ground daily, with a reasonable cover of Paspalum and Eragrostis grasses. A purchased "layers-mash", oystershell grit and clean water were available to the birds *ad. lib.* Throughout the year only very sick and dead birds were removed and set for post-mortem examination.

RESULTS

Egg production figures over the year were as follows:—

Month	*Egg Production Per cent*
March	58
April	57
May	52
June	56
July	63
August	63
September	46
October	39
November	33
December	41
January	41
February	41

During the 12 months, 3,446 eggs were produced in 6,879 hen days, an average production rate of 50 per cent. The hen-housed average of the birds was 157 eggs. The hen-housed average of a group of birds is found by dividing the total number of eggs produced by the number of birds present at the beginning of the year.

Food consumption totalled 2,424 lb. of layers-mash in 7,974 bird days, an average of 4.9 oz. per bird per day.

The culling and mortality rate was 22 per cent, six birds out of the 25 not completing a year's production. The results of post-mortem examinations were as follows:—

2 cases—egg peritonitis.

2 cases—impaction of vent and large intestine.

1 case—liver congested and enlarged, cause unknown.

1 case—cirrhosis of the liver.

Costings of the birds for egg production were as follows:—

	Sh.
22 point of lay pullets at Sh. 20 each	440
3 stock cockerels at Sh. 15 each ..	45
2,424 lb. layers-mash at cts. 25⅓ per lb. (one ton lots)	614
50 lb. oystershell grit	16
Depreciation on fold unit (20 per cent of Sh. 350)	70
Labour (1/30 of one man at Sh. 125 per month)	50
Interest on capital (5 per cent of Sh. 1,000)	50
	1,285

	Sh.
Revenue from sale of 16 old hens and 3 cockerels at Sh. 8 each ..	152

The cost of production of 287 dozen hatching eggs was therefore Sh. 1,133 or Sh. 3/95 per dozen.

In the case of table egg production, three extra point-of-lay pullets would be substituted for the three stock cockerels at an extra cost of Sh. 15. The total egg yield would be increased by three times the hen-housed average of the flock, i.e. by 39 dozen eggs. At the same mortality level of the female stock, a total of 18 old hens would be available for sale at the end of the year, bringing in Sh. 144 or Sh. 8 less than previously. Thus the cost of production of 326 dozen table eggs would be Sh. 1,156 or Sh. 3/55 per dozen.

From these figures it is obvious that a farmer must have an assured return of at least Sh. 3/55 per dozen for his eggs before small scale production in Uganda under this system is a worthwhile undertaking. When a farmer rears his own laying stock from the day-old stage to maturity, his initial cost of point of lay pullets may be reduced by up to 20 per cent. The culling of stock throughout the year to prevent carrying birds out of production will effect a small economy in food consumption. The cost of production by individual farmers will thus vary up or down the scale from Sh. 3/55 per dozen depending on the efficiency of the farmer.

Small scale egg production in Uganda under the management of an African poultry farmer was examined with the following results. Average egg production was 50 per cent, with a hen-housed average of 157 eggs per bird. Consumption of a balanced layers mash was 4.9 oz. per bird per day. Eighty per cent of the flock completed one year's production. The cost of production of hatching eggs was Sh. 3/95 per dozen, while the cost of production of table eggs was Sh. 3/55 per dozen.

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EXPERIMENTS ON THE CRIB STORAGE OF MAIZE IN UGANDA

By **J. C. Davies, Department of Agriculture, Uganda**

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Insects cause considerable losses in stored maize in Uganda whether in bags, on the cob in African granaries or in cribs. At Kawanda weight losses of between 5 and 10 per cent have been demonstrated (Michelmore, unpublished data 1949-51), and subsequent surveys have shown that these estimates were conservative. In early 1956 maize which had been lying in a Kawanda crib for over eight months was examined for insect damage. It appeared that cobs with tight, long, well fitting sheaths with the "silk" intact were offered a degree of protection; to test this hypothesis one hundred cobs with tight sheaths and one hundred cobs with loose or damaged sheaths were selected at random from the crib and shelled in a hand sheller. Each sample was kept separate and after thorough mixing five sub-samples of one thousand grains from each bulk were examined and weighed (Table 1).

Table I.—Comparison of the Number of Bored Grains per 1,000 taken from Tight Sheathed and Loose Sheathed Cobs, with Total Sample Weights

Sample No.	No. of Grains Insect Bored	Weight Total of Sample in Grams
Tight Seath		
1	56	403
2	49	400
3	71	400
4	62	382
5	62	400
	Average weight	397
	Moisture content	12·7%
Loose Seath—		
1	865	310
2	854	305
3	855	310
4	757	340
5	812	325
	Average weight	318
	Moisture content	13·5%

From these figures it is apparent that there is a weight loss of 19.9 per cent, which if all insect fragments and larvae were removed would be well over 20 per cent. A further factor to be taken into consideration is that the insects eat the more palatable part of the grain leaving the outer skin which is of lower food value. Thus, of every five cobs harvested only the equivalent of four are available for human consumption after an eight months storage period; the other provides sustenance for insects.

The main insect pests recorded from maize stored in cribs at Kawanda are *Calandra oryzae* L., *Tribolium castaneum* Hbst., *Tenebroides mauritanicus* L., *Cryptolestes minutus* Ol., *Ahasverus advena* Waltl., *Oryzaephilus mercator* Fav., and *Carpophilus dimidiatus* F. Moth infestation is normally very slight. The chief and by far the most important pest is *C. oryzae*.

To follow up these observations a series of experiments were conducted at Kawanda and Namalere to investigate the storage of maize in cribs in Uganda conditions.

EXPERIMENT 1

Maize brought in from the field in August 1957, was sun dried on barbeques from a moisture content of 30 per cent to 20 per cent, and was then sorted into cobs with good tight sheaths and cobs with loose or damaged sheaths. Sorting took $47\frac{1}{4}$ man-hours in which time 16,459 cobs with tight sheaths (6,074 lb.) and 24,605 cobs with loose sheaths (8,055 lb.) were examined. The sorted maize was then placed in a crib 25 ft. long by 9 ft. wide constructed of angle iron and $\frac{1}{2}$ in. expanded metal. The crib was divided into two by a wood and wire netting partition. The crib was thoroughly swept prior to introducing the tight sheathed maize into one half and the loose sheathed maize into the other. No insecticide was used on the fabric.

The only stored product insect recorded at the start of the experiment was *Carpophilus dimidiatus* F., a sap feeder usually associated with damp produce.

Sampling

Samples of 100 cobs from each sheath category were taken at the start of the experiment, the cobs being chosen at random from the bulk during sorting. After shelling in a hand sheller each sample was thoroughly mixed and two separate sub-samples of 1,000 grains counted out of each. These sub-samples were examined for insect boring, mould, germination and mechanical damage. Further samples were placed in sealed screw top bottles for moisture content determination. The grain for moisture determination was ground in an electric mill fitted with a 1 mm. sieve, placed in aluminium slip lid tins, and heated in an electric oven at 130° F. for one hour, four lots of 5 gm. of ground meal were used. After heating the tins were cooled in a desiccator containing calcium chloride. All weights were taken on an electric balance.

Since maize was required for farm use it was necessary to draw off 10 to 20 bags per month from the crib. As each lot was removed, 100 cobs of each type were taken at random from the bulk, and treated as outlined above.

Observations

At the start of the experiment the percentages of bored grain in tight-sheathed and loose-sheathed maize were 2.05 and 1.85 respectively. Boring was almost entirely by lepidopterous larvae. Although the number of stored products insects actually recorded in the maize at the beginning of the experiment was negligible, a rise in the percentage of bored grains was immediately apparent in the loose-sheathed maize. This rise continued throughout the storage period to reach 74.5 per cent after seven months storage. In the tight-sheathed maize the initial increase in boring was steady but small over the first four to five months; thereafter damage increased rapidly. After five months the rate of boring increased rapidly. (*See* Fig. 1.)

Figures calculated from samples by direct weighing at the end of the storage period show a 12.25 per cent weight loss in the loose sheath samples compared with the tight. An effort was made to obtain a more accurate picture of weight loss due to insects over the whole period of storage. From weights taken at the monthly samplings the average weights of individual bored and unbored grains were calculated for each 1,000 grain sub-sample. This obviated the necessity for calculating moisture content loss since it could be assumed that the moisture content of infested and non-infested grains within the same sub-sample did not differ appreciably. By using a simple proportion and the average number of grains bored and unbored in each set of monthly samples it was possible to arrive at a damage figure, e.g. on 9.4.58 in the loose-sheathed maize the average number of bored grains was 744 per 1,000, each bored grain having an average weight of 0.275 grammes; the average number of unbored grains was 206 of average individual weight 0.382 grammes. The total weight of the sample was 283.29 grammes, but if all the grains were unbored calculated weight would be 362.90, indicating a loss of 79.61 grammes or 21.93 per cent. The weight loss in all samples increases with time. The figures for the loose sheath reflect the steady and continuous rise in infestation while those for the tight sheath show only a slight rise for the first four months, followed by a substantial increase. (*See* Table II.)

TABLE II.—PERCENTAGE WEIGHT LOSS IN MAIZE WITH TIGHT AND LOOSE SHEATH OVER THE STORAGE PERIOD

Month	Loose Sheath	Tight Sheath
2	3·03	0·44
4	6·34	1·36
6	12·62	6·81
7	21·93	8·87

A tight sheath is therefore beneficial but with prolonged storage and rising infestation the sheath appears to become less effective, i.e. after two months storage the number of grains bored is eight times greater in the loose sheaths than the tight, after four months more than four times, at seven months more than two. It is undoubtedly worth encouraging a peasant farmer to sort his maize if the maize is only to be stored for four to five months. The badly sheathed maize should be used up first. It is however obvious that if maize is to be stored in the crib in Uganda for six months or more, insecticide must be used.

A criticism often made of crib storage of maize in the Buganda area is that drying is inefficient and mould growth heavy. Moisture content over the seven-month storage period was carefully recorded. During the first two months a rapid drop from about 19 per cent, the initial moisture content, to 15 per cent occurred. The lowest figures recorded for any sample were 13.2 per cent in the tight sheaths and 13.4 per cent for the loose sheaths. The tight sheath did not appear to affect drying significantly. With the onset of the rains moisture content rose slightly but no marked increase in mould or number of grains germinating occurred over the whole storage period. The crib was sheltered from the worse effects of driving rain by the use of papyrus screens which did not appear to hinder drying.

EXPERIMENT 2

Since, from the results of the previous experiment it was obvious that insecticidal treatment was necessary if maize was to be stored for six months or more in Uganda, an experiment was laid down using gamma-BHC dust. This dust is already extensively used in Kenya as a result of the work of Kockum (1953), and the dosage used for the experiment was that recommended by the Kenya authorities, i.e. 8 oz. of 0.5 per cent gamma-BHC to 200 lb. (9 cu. ft.) of cobs.

The maize was stored in a small 2-ton crib which was erected at Namalere Farm, approximately two miles from Kawanda. The crib was constructed of poles and ½ in. expanded metal and stood one foot off the ground on concrete pillars. A crib of this size is thought to be well within the means of an African grower.

One half of the maize was desheathed and treated in batches during loading into one half of the crib. It was found convenient to treat four bags of cobs at a time. The other half of the crib was filled when insecticidal treatment was complete, with ordinary sheathed maize.

Sampling

On arrival from the field a random sample of several hundred cobs was taken, shelled, bulked and sub-sampled. Initial infestation was determined as in Experiment 1 by counting out 1,000 grain samples from the bulk. Thereafter random samples of 50 cobs from each side of the crib were removed at monthly intervals. After shelling and thorough mixing two large sub-samples were taken from each bulk and from each sub-sample two separate lots of 1,000 grains were taken and examined for insect boring, mould, germination and mechanical damage.

Samples were taken for moisture content and routine determinations carried out using a Marconi moisture meter on a finely ground sample. Check determinations were made using the oven method outlined above.

Very few of the commoner grain storage pests were recorded in the maize at the start of the experiment but *Carpophilus dimidiatus* F., *Ahasverus advena* Waltl. *Brachypeplus* sp. and a few *Cryptolestes* sp. were recorded.

Observations

The course of the infestation in the crib is shown clearly in the graph (*see* Fig. 2). Over the first two months the increase in the percentage of bored grains was small in the untreated maize but afterwards the infestation rose sharply. Over the whole period of storage the infestation in the treated maize remained extremely low.

Weight loss was calculated using the method described in the first experiment. In the untreated maize a loss of 0.71 per cent was recorded at two months, 3.49 per cent at four months and 8.84 per cent at six months. The loss in the treated maize was consistently low, being only 0.80 per cent at six months.

Unfortunately after six months storage the maize was required for farm use and it was necessary to terminate the experiment. One week after the six-month sampling a large random quantity of maize from each side of the crib was shelled. Six separate lots of 1,000 grains from each bulk were examined after thorough mixing. Figures compared favourably with those taken the previous week, the average number of bored grains in the treated being 1.8 per cent and in the untreated 56.0 per cent.

Taking 8 per cent as the calculated weight loss at six months there is a saving of 16 lb. per 200 lb. of shelled maize, which is equivalent to Sh. 1/60 per bag at a price of Sh. 20 per bag or Sh. 3/20 per bag at a common late season price of Sh. 40 per bag. Cost of treatment is approximately 25 cents for 200 lb. of shelled maize. Also the condition and appearance of the maize after treatment is vastly superior, and it has been shown that insect fragments and frass detract from the appearance of posho milled from infested maize. (Coaker and Davies, 1957.)

EXPERIMENT 3

A further experiment to test a half-dose against the full dose was carried out at Kawanda, the object being to provide a cheaper treatment for the peasant farmer. The maize used for this experiment had been harvested for some time before loading into the crib, hence initial infestation was heavier than in either of the two previous experiments and *Calandra oryzae* L. was recorded before maize was placed in the crib.

Sampling

Because the maize had been held for some time prior to treatment a very large number of cobs were taken regularly as the crib was filled

These were then shelled and bulked and in all over a dozen seperate 1,000-grain samples were counted out and examined.

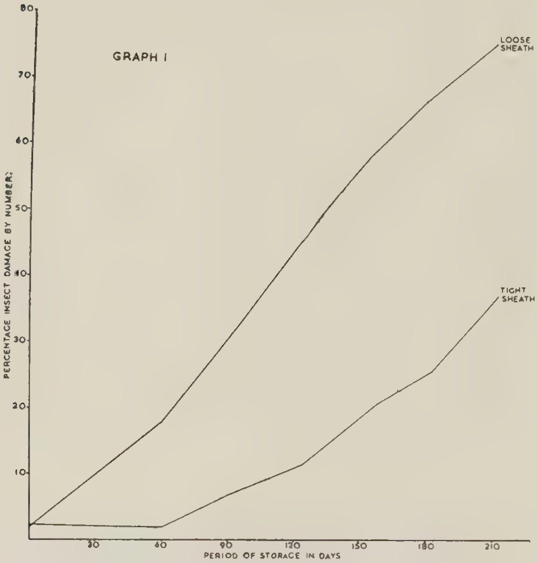
In the course of loading the crib wire baskets each containing 50 selected cobs were placed at strategic points in the crib in an effort to gauge the efficacy of the treatment over a known period. The baskets were located at three levels in the crib: four were placed in the corners at the bottom of the crib, a further four 12 in. to 18 in. below the top surface of the maize, and one basket was placed in the middle of each treated bulk. It was necessary to bury the top baskets beneath the level of the maize as it was known that maize would be drawn off for farm use at intervals. The baskets were left in situ for 225 days, but towards the end of the period the top set became more or less completely exposed in both treatments.

When maize was needed for farm use bulks were drawn off from both treatments. 100 cobs from each treatment were chosen at random and shelled saparately in a hand sheller and six separate 1,000-grain sub-samples counted out from each.

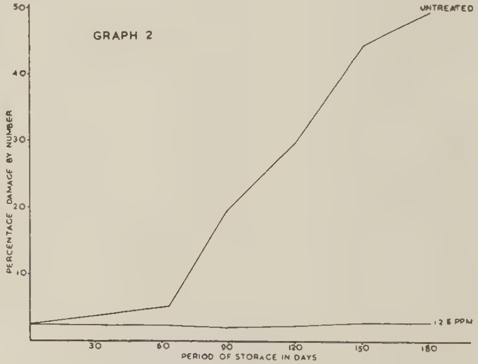
The baskets were removed on the 225th day, the contents of each shelled separately, and from each bulk two separate 1,000-grain samples were counted out and examined. Sampling of the main bulk of maize was continued after the removal of the baskets and six sub-samples of 1,000 grains examined as above at regular intervals.

Observations

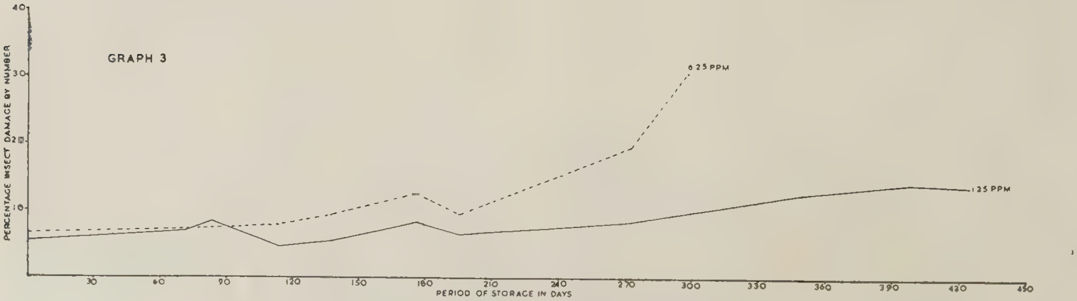
The progress of the infestation for each treatment is clearly shown in Fig. 3. There is some variation in the first few sampling figures as it was not possible to get a random sample from the whole bulk without disturbing the baskets. Sampling was therefore confined to the top layer of maize which was drawn off for farm use. The main trend is however clear.



COMPARISON OF TIGHT SHEATH VERSUS LOOSE SHEATH AS PROTECTION FOR COB MAIZE IN CRIB



COMPARISON OF INSECTICIDE TREATMENT VERSUS IN SHEATH STORAGE



COMPARISON OF FULL DOSE (12·5 PPM) VERSUS HALF DOSE (6·25 PPM)

The initial percentage of bored grains in the "full" treatment was 5.4 and in the "half" treatment 6.6. In the former there was a slight rise in the percentage of bored grains over the whole storage period but after 424 days this was only 13.14 per cent. The maize treated with the half dose showed very little infestation increase over the first 200 days, after which the treatment became less effective, the percentage bored grains rising exponentially to more than 30 per cent at 290 days.

An analysis of variance was carried out on the figures obtained from the basket samples and it was shown that there was a significant difference in the number of grains bored at the top, middle and bottom levels. The bottom was by far the most heavily bored and differed significantly from the others at the 1 per cent level. The middle differed significantly from the top at the 5 per cent level. There was a significant effect in favour of the higher dosage and no interaction between dosage and level in the crib. These results were confirmed by X_2 tests, and agree closely with those obtained at the Scott Agricultural Laboratories in Kenya by Kockum (1953).

The moisture content taken by the oven method remained satisfactory throughout the storage period and there was no significant rise in the mould count. The lowest moisture content in the whole series of experiments was obtained in this trial, 12.5 to 12.6 per cent being recorded in February.

DISCUSSION

It is clear that for Uganda conditions treatment of maize with gamma-BHC is advisable if the maize is to be stored in excess of five months. This treatment is both economic and easy. There is no evidence for the contention that crib drying in Buganda is inadvisable and/or inefficient. Satisfactory moisture contents were obtained in trials over three seasons, but it is advisable to use a papyrus screen to protect cribs from the worst effects of driving rain.

Experiment 3 conclusively proves that maize can be successfully kept in a satisfactory condition for 15 months using 8 oz. of 0.5 per cent gamma-BHC to 9 cu. ft. of cobs. There is evidence that some increase in infestation may be expected in the outside cobs, where the insecticide is exposed to the direct effects of the weather. It is doubtful whether special treatment of the crib, e.g. the use of treated hessian as in Kenya (Kockum, 1959) to protect this outside layer can be economically justified in Uganda peasant farmer conditions since insect boring remains below 10 per cent over a storage period of one year. A possible remedy is to dust the exposed layer at two-three monthly intervals with the powder.

Use of the full dose is recommended even if the maize is disposed of or sold after six months. The purchaser will obtain relatively insect free maize and this benefit should be passed on to the consumer through better quality posho.

SUMMARY

1. Trials on the crib storage of maize in Uganda are described.
2. 8 oz. of 0.5 per cent gamma-BHC gives excellent and economic control of storage pests for over 15 months.

ACKNOWLEDGEMENTS

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Permission to publish this paper has been obtained from the Director of Agriculture, Uganda.

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REVIEW

THE APPLICATION OF GENETICS TO COTTON IMPROVEMENT, by Sir Joseph Hutchinson, published by the Cambridge University Press in association with the Empire Cotton Growing Corporation, 1959. Price 15*s*. net.

This short book makes highly interesting reading. Like good conversation it is stimulating; it is not necessary to agree with the writer 100 per cent. It should be read by all concerned with cotton improvement; but I have found it also to be of much interest to others concerned with tropical agriculture, though scarcely knowing one end of a cotton plant from the other. It is, needless to say, decisively written, though in parts, uneven in presentation, and controversial.

The first three chapters deal with the possible origins and spread of the Cultivated Cottons, and cover in a more popular form part of the same field as the 1949 monograph, *The Evolution of* Gossypium, now accepted, I understand, as the standard taxonomic classification of the genus.

The following three chapters deal with Evolution in the Cottons, Breeding Systems, and, of especial interest in East Africa, The Improvement of African Cottons. These chapters are written in a genetical climate of thought, but only to a limited extent do they deal with an understanding of the gene complexes involved in bringing about cotton improvement. Even Knight's genetical studies in the Sudan have proved not to have general application to cotton improvement in the completely different environments of East Africa. To the working cotton-breeder, therefore, the book does not seem to merit the title *The Application of Genetics to Cotton Improvement.*

T. K., in a review of this book in the January number of the *Empire Cotton Growing Review,* refers to "charting the course and patterns of evolution in *Gossypium*". By the very nature of things this must be highly speculative and therefore controversial. There are very few of us in a position to comment constructively on the views set out in the first three chapters, fascinatingly interesting though they are. They represent "the logical probabilities", on the evidence available, as they appear to one of the foremost workers in this field.

One or two of the views expressed in the following three chapters, unsupported by any evidence, are open to criticism, and to that extent then detract somewhat from the level of presentation.

On page 55, in discussing jassid resistance, Sir Joseph states that there is good reason to believe that the introduced Upland varieties of the first decade of the present century, that provided the basic stocks for (East) Africa, contained some moderately hairy plants. Why then propound the very speculative hypothesis, without any evidence, that "it seems *probable* that the hair-length factors", available in the U4s and in the East African cottons, "have come from Cambodia"? From acquaintance with the Barberton and Gatooma stocks, and having originated the Ukiriguru, Lake Province, Tanganyika, stocks, considering the timing of the growing of Cambodia at these stations, and other factors, I consider this highly unlikely. It is very much more likely that there has been an exploiting of hairiness genes from the original basic stocks.

Equally, page 71, from the timing of introductions of U4 material, and for other reasons, it is most highly unlikely that, at Ukiriguru, U4 stocks "contributed to the gene pool from which more recent improved strains" for the Lake Province of Tanganyika "have been derived"—incidentally all Ukiriguru strains.

There is bacterial blight resistance in the straight Ukiriguru material of "local" origin, and in Cambodia growing in Thailand, of considerable value in cultivation, though not up to the resistance standards of Albar. Is it necessary to assume that these stocks "have had in the past direct contact with *punctatum*", and received this resistance by introgression? page 54. There are characters in the gene pools, with which I have been associated, not immediately obvious, but waiting to be exploited as the need arises—for example, in the Ukiriguru material some unexpected resistance to *Fusarium* wilt. The characters desired have to be searched for.

Probably the most important contribution from Namulonge to other areas has been the production of Albar, page 74. There is here reference to the release of genetic variance following hybridization between two races of the same species of *Gossypium*. Throughout the chapters concerned with breeding there are a number of references to the need for maintaining variability as a basis for selection. If genes for a character or characters desired are not there, however much working-over of material is done, and by whatever techniques, the end result desired cannot be reached.

This has bearing on the use of the Selection Index, page 60, and then, as I see it, its use is only for relatively inbred material. I have never quite understood how a relatively precise yield advance of the order of 4 per cent per generation is achieved, page 63. In my Tanganyika experience the environmental influences allow large advances to show up in some seasons and in some areas, and little advance in others; then genetic variation is masked because of environmental fluctuations.

One of the diploid parents of the allopolyploids, from which modern cottons have emerged, may, it is suggested, have come out of Africa. Coming to more recent times, we read that it is only about 140 years ago since the perennial *G. barbadense* form *vitifolium* was taken to Egypt from the Sudan, having been carried by trade and slave routes from West Africa. Later, segregates from hybrids between *vitifolium* and Sea Island types were to be exploited to provide the annual more modern Egyptian types. It is less than 60 years ago that Upland types were first introduced into East and Central Africa. Now cotton is "one of the economic pillars of the continent".

All in all this is a book to be read critically, and enjoyed; not only by cotton men.

J. E. P.

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